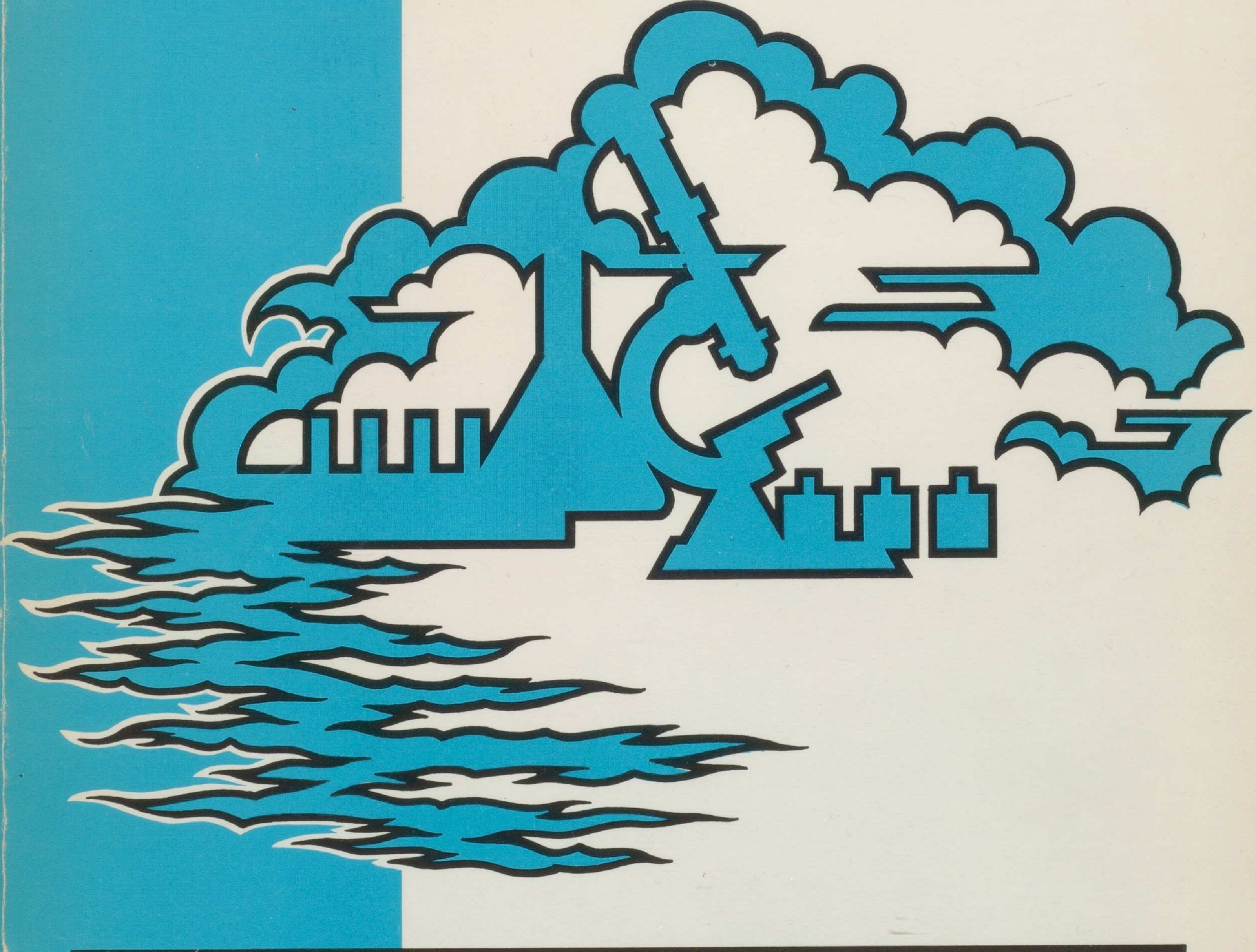
1979-07-01

Great Lakes Science Advisory Board: Annual Report to the International Joint Commission, [1978], Presented July 1979, Windsor, Ontario

Great Lakes Science Advisory Board

GREAT LAKES
SCIENCE ADVISORY BOARD



INTERNATIONAL
JOINT
COMMISSION

ANNUAL REPORT OF THE
SCIENCE ADVISORY BOARD
JULY 1979

GREAT LAKES SCIENCE ADVISORY BOARD

ANNUAL REPORT TO THE INTERNATIONAL JOINT COMMISSION

The Research Advisory Board
effective November 22, 1978
became the Science Advisory Board.

PRESENTED
JULY 1979
WINDSOR, ONTARIO

INTERNATIONAL JOINT COMMISSION

Great Lakes Science Advisory Board

June 1979

International Joint Commission

Canada and United States

Gentlemen:

The International Great Lakes Science Advisory Board, in partial fulfillment of its responsibility under the Water Quality Agreement of 1978, is submitting the following Annual Report on the activities of the Board and its working committees and task forces.

Respectfully submitted,

Dr. Donald I. Mount
Chairman
United States Section

Dr. G. Keith Rodgers
Chairman
Canadian Section

TABLE OF CONTENTS

SUMMARY

By example of previous cultural development and its subsequent effects on the biota and water quality of the Great Lakes Basin, the Science Advisory Board re-iterates the significance of understanding and considering the diverse interactions which occur within the chemical, physical, biological and societal components within the Great Lakes Basin Ecosystem. The Board addresses four current and urgent Great Lakes issues in terms of an ecosystem approach to illustrate to the Commission and the Parties the advantages of such an approach and to assess the gaps in knowledge. The four issues addressed by the Board are as follows:

LONG RANGE TRANSPORT OF ATMOSPHERIC POLLUTANTS

Acid precipitation is discussed to illustrate the broad implications of long range transport of atmospheric pollutants in the Great Lakes Basin Ecosystem. Topics reviewed by the Board pertinent to acid precipitation include: ecological effects; human health; import and export to and from the Basin; energy consumption; ameliorative and corrective measures; air pollution control technology; regulatory options; and, information needs. The Board concluded that the pH in the open waters of the Great Lakes themselves is not expected to be lowered significantly. The Great Lakes are large in volume and relatively well buffered. However, the Board is concerned that acid precipitation may indirectly result in "transboundary injury to health or property"; injuries which are known to occur or which could be expected to occur through the interacting elements of the hydrosphere, atmosphere, lithosphere, and biota of the Great Lakes Basin Ecosystem as defined in the 1978 Great Lakes Water Quality Agreement. The Great Lakes Basin is being impacted by air emissions from sources outside the Basin and emissions within the Basin are being exported to ecosystems outside the Basin. Legislative and socio-economic concerns will have to be broadened. The Board endorses a proposed research program now before the U.S. Council on Environmental Quality which will address current information needs on acid precipitation.

As a result of its concerns, the Board recommends that the Parties be encouraged to formulate a reference on long range transport of airborne pollutants with special attention to acid rain. Also, the Board recommends that the Commission immediately implement, under Article VII(6) of the Great Lakes Water Quality Agreement, liaison among institutions established under the 1909 Boundary Waters Treaty, appropriate U.S. and Canadian agencies and international organizations to ascertain and ensure that all facets and concerns outlined in the Board report are being adequately considered. Particular emphasis should be placed on the long range transport of acid rain.

TOXIC SUBSTANCE CONTROL

The computer data base developed on behalf of the Board is now operational. It has been designed to aid in forecasting those chemicals manufactured or used in the Basin with potential to persist and bioaccumulate with the Ecosystem. The Board notes that many other multi-national and multi-agency efforts are underway to evaluate the effects of chemical substances in the Ecosystem. As a result the Board recommends that future hazard assessment efforts in the Great Lakes Basin be carried out in the context of the identified multi-agency and multi-national efforts which are described in the report.

A review of Canadian and United States research programs implies a significant concern by governments, industry and unversities on the potential effects of man-made chemicals in the environment. The Board stresses the need for continued high priority for such investigations and for current development of legislative and regulatory actions, until there is a better understanding of the effects of contaminants on the health of the ecosystem, including man. The Board emphasized these points for two reasons: firstly, the Board feels that the dispersal and the subsequent potential effects of toxic substances in the Great Lakes should remain the highest priority issue for the management of the Great Lakes. Secondly, the Board's concern that the recent economic conditions in both U.S. and Canada may result in political pressures to ease concerns, legislation and regulations with regard to the discharge of potential contaminants.

The Board reviewed the Annexes 10 and 12 of the 1978 Great Lakes Water Quality Agreement which pertain to the control of chemical contaminants. To address both Annexes, an approach is recommended which requires the concerted efforts of both the Science Advisory Board and the Water Quality Board. The Science Advisory Board requests the International Joint Commission to obtain from the parties an immediate commitment to review the Board's recommended approach for consideration of adopting the procedure to implement those portions of the Agreement.

In addition to developing objectives for specific contaminants, a committee of the Board is developing a framework to develop holistic aquatic ecosystem objectives. The approach would, for example, attempt to develop a means of determining effects of various stresses on the biotic community through observation of the changes in community structure and behavior. Such an approach has been undertaken by several international organizations, and offers the potential of detecting the effects of cultural, socio-economic and technological changes on the Great Lakes.

SOCIO-ECONOMIC FUTURES

The concerns of the 1972 and 1978 Great Lakes Water Quality Agreements have primarily addressed chemical stresses on the Great Lakes Ecosystem. Additional stresses are possible from other human activities. A workshop was sponsored by one of the Board's committees to identify problems which may emerge within the Basin as a result of future trends in, for example, urban growth, energy and transportation. The findings of the workshop are expected to be available in the fall of 1979.

Environmental mapping can improve the understanding of the Great Lakes ecosystem and subsequently aid in planning and management decisions. A task force of the Board outlined several approaches which could be taken to initiate an environmental mapping activity. However, strong differences in opinion on several aspects of mapping still remain. The Board is aware that several Great Lakes institutions are interested in mapping, and as a result, requests that those institutions be identified and subsequently implement a coordinated environmental mapping effort.

GREAT LAKES EUTROPHICATION

The Board reviews the several and diverse activities of its task forces and committees which are addressing the issue of Great Lakes eutrophication. The activities address: phosphorus management strategies; health effects of non-NTA detergent builders; ecological effects of non-phosphate detergent builders; sludge disposal research; bioavailability of phosphorus; and, operation and maintenance of municipal wastewater treatment plants. The Science Advisory Board also comments briefly on land application of municipal wastewaters.

RECOMMENDATIONS

The Great Lakes Science Advisory Board recommends that the International Joint Commission:

1. Immediately implement, as specified in Article VII(6) of the 1978 Great Lakes Water Quality Agreement, liaison among institutions established under the 1909 Boundary Waters Treaty, appropriate U.S. and Canadian agencies, and international organizations which address concerns relevant to the Great Lakes Basin Ecosystem to ascertain and ensure that all facets and concerns of the Great Lakes Basin Ecosystem, as outlined in this report, are adequately considered. Particular emphasis on the problems associated with long range transport of airborne pollutants should be given high priority.

2. Encourage the Parties to formulate a reference within the context of an ecosystem approach on the causes, effects and measures for the control of long range transport of airborne pollutants with special attention to acid rain. Such action will serve to accelerate efforts to develop necessary information for rapid action.

3. Request that agencies responsible for assessment of living resources, such as fish stocks, dedicate and/or expand a portion of their current management programs which would coordinate with air quality and water quality surveys enabling improved assessment and understanding of the overall quality of the Great Lakes Basin Ecosystem.

4. Urge continued high priority for research and legislative/regulatory action regarding the dispersal of man-made chemicals in the environment.

5. Urge that efforts for hazard assessment of man-made chemicals in the Great Lakes Basin, be carried out in the context of ongoing multi-agency and multi-national efforts as identified in the Board's report.

6. Obtain from the Parties an immediate commitment to review the Science Advisory Board's recommended procedure for addressing Annexes 10 and 12 of the 1978 Great Lakes Water Quality Agreement.

7. Request the Parties to identify United States and Canadian institutions with interests in environmental mapping and to identify agencies with resources which can be allocated to an initial effort. Contingent upon adequate agency support the Commission should establish a task force to coordinate and assure implementation. Topics recommended for consideration are: toxic contaminants, eutrophication and rehabilitation.

8. Encourage the Parties to identify, within the Basin, land areas generally suitable for land application of municipal wastewater on the basis of soil and groundwater characteristics, agricultural opportunities, climate, as well as present and anticipated land use patterns in an effort to ensure consideration of the use of this technology.

1 INTRODUCTION

The joint efforts designated under the 1972 and 1978 Great Lakes Water Quality Agreements essentially address the presence, consequences and control of chemicals found in the Great Lakes. Steadily, the list of chemicals of concern has grown from fertilizers, insecticides and herbicides which enter the aquatic environment to wastes containing chemicals resulting from products manufactured, transported or used by modern society.

In this era of rapid change, there is a need for systematic identification, analysis and evaluation of the effects of man's activities on the Great Lakes Ecosystem. If we can anticipate the consequences, both beneficial and detrimental, resulting from: new technologies; changes in utilization of existing technologies; and, changing demographic, socio-economic and cultural characteristics, then society can make conscious decisions to influence the ultimate outcome of these changes. As a result, the Science Advisory Board has advocated an ecosystem approach which can: (a) anticipate future problems which may occur as a result of man's activities; (b) define management options; and (c) expand beyond the realm of "chemicals and the Great Lakes" to forestall problems associated with, for example, demographic and cultural changes. Using this approach the Board may be in a better position to assess the relevant state of knowledge with regard to future problems and subsequently define information gaps which must be addressed to aid in the definition of management options. This approach is consistent with the Board's previously expressed conviction that:

> "Planning and management of such a priceless resource as the Great Lakes requires more than a knowledge of the chemical and physical water quality; it requires an understanding of the total ecosystem and the diverse interactions which occur within its chemical, physical, biological and societal components."

2 CULTURAL DEVELOPMENT RELEVANT TO THE GREAT LAKES

Many factors have contributed to the changes which have occurred in the Great Lakes Basin subsequent to its early pristine condition. New species have entered the Basin; tributaries have been modified; and marshes were drained; and lumbering practices and clearing for agriculture have deforested vast areas of the watershed. The Board neither condemns nor condones these past changes. To support a growing society and its technology, forested areas had to be removed for crops, dwellings and industry. However, these practices set in motion a series of events which were not necessarily planned and not all of which were desireable. Options for society today are, in part, constrained by those past decisions. The Board emphasizes that future management decisions should be made with recognition of the interrelationship of the many ecosystem components or events.

Jesuit missionaries' diaries which were written between 1610 to 1791 described vegetation and wildlife in the Basin which was representative of mature climax communities. Conifers and hardwoods were the dominant forest flora. Wet and dry areas of the Basin contained savanna grasslands, shrubs, dune and sedge communities. Passenger pigeons and elk were found throughout the forest communities. Extensive areas of swamps and marshes provided shelter and breeding sites for an array of bird and fish species. The European settlers wanted different habitats to provide for their wishes and in that pursuit changed the Great Lakes and its drainage basin as well.

The dense forest cover which stablized the watershed by restricting water runoff, soil erosion and siltation, was either harvested or burned. With the loss of forest shade, streams which once delivered continuous, stable flow of cool water to the lakes year round were subject to increased seasonal and diurnal fluctuations. Winter accumulations of snow no longer persisted into the late spring. Runoff patterns changed. Streams were modified as a result of their use for transportation. The rate of erosion and associated contributions of nutrients increased and subsequently impacted the waters of the Great Lakes.

New plant and animal communities appeared on the deforested land. One of the plant species of a new community is ragweed. Its abundance has certainly been felt by man in the form of "hay fever." Bird populations underwent shifts in species dominance from those representative of woodlands to those of open grassland communities. The eastern meadowlark expanded its range into the newly opened fields of the Basin. Although wasteful exploitation is cited as the principal factor in the extinction of the passenger pigeon, deforestation also was a contributing factor. The mature stands of trees necessary for feeding and nesting had been removed.

As well as altering terresterial ecology, deforestation also altered aquatic communities. Atlantic salmon was once an abundant commercially important species in Lake Ontario. It declined in abundance by about 1850. Exploitation probably played a role in this decline. Perhaps of equal or greater importance in the decline of the Atlantic salmon was the rise in stream temperatures and siltation which resulted from lack of forest shading, cover and damming of streams. These streams served as spawning and nursery areas for the fish. Programs to reintroduce Atlantic salmon have been attempted over the years but all have failed. Because historical changes are imcompletely understood and documentation lacking, various scenarios have been proposed to describe other changes which have occurred within the aquatic communities as a result of deforestation. For example, the increased water temperatures of the Great Lakes tributaries are considered by some investigators to have created favorable conditions for the invasion and reproduction of the parasitic sea lamprey. Feeding on larger fish, such as the lake trout, the sea lamprey reduced the abundance of these large predatory species upsetting the balance in the entire food chain.

Clearly, the loss of forest cover created a rippling effect which was felt both directly and indirectly throughout the entire Great Lakes Basin - effects which exemplify the interrelationship of air, land, water and living organisms, including man.

Our Ecosystem is the product of its history.

3 FISH RESOURCES AS INDICATORS OF ECOSYSTEM QUALITY

The efforts to clean up the Great Lakes have been sizeable and costly. Most citizens perceive the effectiveness of these efforts in terms of tangible benefits such as progress in restoring the lakes' valuable fishery resources. In pointing to indicators of new vitality in the lakes, the Board does not imply that apparently healthier fish communities are necessarily the sole, direct, or unequivocal result of improved water quality and a generally cleaner environment. Analytical and assessment capabilities have not yet advanced to the point where the relative contribution of pollution abatement to the recovery and improvement of Great Lakes fishery resources can be quantitatively (and reliably) discriminated. Other management tactics which may have contributed to such signs and progress include: tighter regulation of fisheries; control of sea lamprey; artificial replenishment of fish stocks; mandated reduction of fish losses associated with large-volume withdrawal of water; and, increasingly closer evaluation and modification of construction permits.

Despite uncertainty about which management tactics are accomplishing the job, fish populations are nonetheless demonstrating an improved status over that which prevailed a decade ago. As examples, the Board deems worthy of note the following recent changes in fish resources and related fisheries:

- Lake whitefish stocks in northern Lake Michigan, Green Bay, and the boundary waters of lakes Superior and Huron continue to prosper. Annual commercial landings of this important resource now average more than twice the volume of the late 1960's.

- Walleye in the western basin of Lake Erie have rebounded dramatically from their impoverished state of less than 10 years ago. The walleye fishery for which western Lake Erie has long been famous is now the focus of experimental intergovernmental management. This fishery is believed to be at or near the Basin's carrying capacity.

- Lake trout in the upper Great Lakes, with some exceptions locally, are performing today to a degree completely unforeseen a dozen or so years ago. As a result of the monumental restoration effort which has applied sea lamprey control and artificial replenishment of fish stocks, the numbers of lake trout in Lake Michigan and in the boundary waters of Lakes Superior and Huron, are as great (or nearly so) as they were during the 20 years of intensive commercial fishing preceding World War II. Re-establishment of naturally reproducing populations, however, continues to be a major challenge.

- Bloaters ("Chubs"), the productivity of which has been long depressed by fishing and possibly by changes in their environment, appear to be making a good comeback in Lake Michigan, as evidenced by the production of relatively larger year classes in the last few years.

- Pacific salmon, especially the chinook and coho, continue to provide an excellent recreational fishery in Lake Michigan, and lesser ones in Lakes Superior, Huron, Ontario, and even Erie. The favorable impact of these introduced species on the angling fraternity and regional economy is well known to anyone conversant with the Great Lakes.

- Brown and rainbow (steelhead) trout, also seem to be on the increase in nearshore areas throughout the Upper Great Lakes and in Lake Ontario. They, too, are making ever-greater contributions to sport fishing at numerous locations on both sides of the international boundary.

- Alewives, gizzard shad, and smelt, represent healthy populations of prey (or forage) now being kept in improved balance: by large and growing stocks of predator species; by commercial fishing such as that for smelt in Lake Erie and alewife in Lake Michigan; and, by natural causes associated with, for example, the severe and protracted winters of recent years.

While the Board is confident of the success these examples represent, we would be remiss if we failed to point out that fish-stocks and fishery rehabilitation in the Great Lakes are still far from having fulfilled the expectations which many hold for the resource. To balance its recognition of the gains achieved so far by Great Lakes water-resource and fishery managers, the Board feels equally obligated to identify as well at least a few of the major fishery-related problems that need to be overcome before the full potential of the lakes as fish producers will again be realized. Some resist solution and others still await attention. All are very complex technically, politically, or both.

- The stocks of yellow perch in southern Lake Michigan, western Lake Erie, and eastern Lake Ontario which are highly valued by commercial and sport fisheries are still at reduced levels and have been slow in responding to management tactics designed to restore their known productive capacity.

- Unresolved conflict between groups competing for the use of certain species - e.g., sport and commercial fishermen for lake trout, walleye, and yellow perch, and Indian-treaty fishermen additionally for lake trout in the upper Great Lakes - hampers application of a unified, more objective fishery management philosophy throughout the lakes.

- Stocks of depleted native populations of lake herring in Lake Superior offer only faint promise of recovery despite the intensive efforts of fishery managers.

- Inadequate commitment of money and manpower continues to constrain the development of comprehensive surveillance and assessment programs for Great Lakes fisheries and fish resources, causing further delay in mounting a basinwide fishery management strategy which many have felt is long-needed.

- o Great Lakes fish habitat, carrying capacity, and productivity continues to be impaired by the effects of cumulative alterations in the environment associated with a variety of proposed water-use and lake-bed/shoreline developments.

- o Great Lakes waters, biota, and fishery products contaminated by toxic substances poses yet another very serious problem, which if unchecked and unresolved, promises to undermine many if not all the fishery-management achievements so far attained, and to preclude the realization of still others underway. Although DDT and mercury residues in some Great Lakes fishes have dropped below guidelines of public health authorities, PCBs, mirex, and dieldrin still pose problems in some areas.

Our intent in discussing the historical perspective of cultural development and fishery resources is to exemplify the diversity of stresses as a result of man's activities which have been placed on a few components of the Great Lakes Basin Ecosystem. These stresses included deforestation, conflicting water uses, shoreline development, introduction of new biological species and discharge of chemical contaminants. The stresses and the consequences are a result of the interactions within components of the ecosystem namely air, land, water and living organisms including man. Management of the Great Lakes resources has in the past focussed only upon a few of the components often without regard for the interactions.

4 ECOSYSTEM APPROACH TO GREAT LAKES WATER QUALITY PROBLEMS

As expressed earlier, the Board is convinced that "planning and management of the Great Lakes requires an understanding of the total Ecosystem and the diverse interactions which occur within its chemical, physical, biological and societal components." Such understanding should minimize stresses and consequences to the Ecosystem as a result of man's activities. In its 1978 report "The Ecosystem Approach" the Board outlined five criteria which should constitute part of a broader approach for application in the Great Lakes Basin Ecosystem:

i) The approach should encompass human activities in a manner suggesting interaction with other parts of nature, rather than viewing man as separate from nature.

ii) The approach should force us to consider interactions of the Great Lakes Basin Ecosystem with areas neighboring the Basin.

iii) The approach should convey a dynamic picture of the transport of energy and materials in the Basin, interrelating industrial activities, geochemical cycles and food chains.

iv) The approach should consider, allow and encourage public interests, attitudes, perceptions and behavior to enable people in the Basin to relate to the biosphere.

v) The approach should recognize the concepts of carrying capacity and resilience, suggesting that there are limits to human activity in the Basin.

The Board thus addresses four current and urgent Great Lakes issues (long range transport of atmospheric pollutants, toxic substance control, socio-economic futures, and eutrophication) in terms of an ecosystem approach to illustrate to the Commission and the Parties the advantages of such an approach and to assess the gaps in knowledge which will facilitate Great Lakes planning and management.

A. Long Range Transport of Atmospheric Pollutants

Man-induced changes are affecting the quality of the earth's atmosphere. These changes are the result of atmospheric emissions from many sources: industrial processes; municipal waste disposal; certain intensive forestry and agricultural processes (i.e. use of pesticides, burning, etc.); transportation; and, household practices (home-heating, aerosol sprays). Meterological processes are known to transport these emissions hundreds or even thousands of kilometers from their original sources. The problems are international in some cases and global in other cases. Their impacts can be great.

Various aspects of this problem, relevant to transboundary effects on water quality, have been described previously to the Commission through studies conducted in support of the Upper Lakes Reference Group and the Pollution from Land Use Activities Reference Group (PLUARG). For example, PLUARG studies calculated that direct atmospheric deposition onto the surface of Lake Superior accounts for 37 percent of the total phosphorus loading (excluding shoreline erosion). In 1975, the Wisconsin Dept. of Natural Resources analyzed snow melt samples for PCB and reported concentrations ranging from 0.17 to 0.24 ppb. Atmospheric fallout was attributed as a major source of PCB contamination in the Lake Michigan fish. It has been reported that DDT from an aerial application in 1974 to control a moth infestation in the Pacific Northwest was detected in the rain falling on the state of New York.

The very nature of long range atmospheric transport and deposition requires that an approach beyond that of traditional air quality and/or water quality approaches be applied to determine appropriate solutions to the array of problems which are known or suspected.

<u>An Ecosystem Approach to the Problem of Acid Precipitation</u>

Acids are chemicals which release hydrogen ions (H^+) in solution. The concentration of hydrogen ions is conveniently expressed as pH which is a negative logarithmic function of hydrogen ion concentration. A solution with a pH of 4 is, because of the logarithmic function, ten times more acid than a solution with a pH of 5.

Acid precipitation (i.e. lowering of pH in rain and snow) is the result of the chemical addition of sulfur oxides (SO_x), nitrogen oxides (NO_x) and in some cases, chlorine into the atmosphere. In the atmosphere these compounds will react with water vapor to form, for example, sulfuric acid, nitric acid and hydrochloric acid. As a result, the rain and snow, contaminated with these acids, is referred to as acid(ic) precipitation. While acid precipitation is the result of only a few air contaminants, the transboundary effects which it exerts on the ecosystem of the Great Lakes Basin and its potentially significant socio-economic consequences provide an appropriate example for the Science Advisory Board to demonstrate the meaning of an ecosystem approach.

The magnitude and degree of the impact of acid precipitation in North America was not fully appreciated widely until publication of a number of recent studies. Parts of the Great Lakes Basin, including the Sudbury, Muskoka and Haliburton areas of Ontario and the Adirondacks of northern New York are now recognized as among some of the most heavily impacted areas in the world. Acid precipitation is a major environmental problem in large areas of the world.

The pH in the open waters of the Great Lakes themselves is not expected to be lowered significantly by acid precipitation because the Great Lakes are large in volume and relatively well buffered. However, increased acidity from acid precipitation has been observed in two bays of Lake Huron. In line with the Commission's mandate, acid precipitation may indirectly result in "transboundary injury to health or property"; injuries which are known to occur or which could be expected to occur through the interacting elements of the hydrosphere, atmosphere, lithosphere, and biota of the Great Lakes Basin Ecosystem as defined in the 1978 Great Lakes Water Quality Agreement.

It is the opinion of the Board that changes comparable to those which have occurred in other areas of the world as a result of acid precipitation are occurring in the Great Lakes Basin; changes which transcend traditional approaches to water quality and air quality. Just as other factors, such as deforestation, have stressed and subsequently altered the Great Lakes ecosystem from that observed by early Jesuit missionaries, so also will acid precipitation. The changes are subtle and may not be fully appreciated unless the ripple effect can be foreseen.

Sources

The burning of fossil fuels rich in sulfur, nitrogen, and in some cases, chlorine as well as the smelting of sulfur-rich ores, is a major source of acidity in precipitation. Currently, an estimated 70 to 75% of the SO_2 in the atmosphere over eastern North America is anthropogenic. In the U.S., coal burned by electrical utilities is the largest source (Figure 1), while in Canada, the smelting of sulfur-rich ores is a critical factor in the acid sensitive eastern region. In 1972, 62% of the man-made emissions of SO_x in Canada came from sulfide-ore smelting and thermal electric generating stations. As they are being transported in the atmosphere, the oxides are oxidized further (e.g. SO_2 to SO_3) by ultra-violet light and ozone. They are then hydrolyzed to form sulfuric

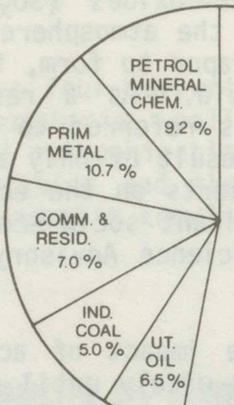


Fig. 1 SOURCES OF SULFUR DIOXIDE EMITTED IN UNITED STATES, 1973. (DATA FROM U.S. EPA.)

acid, which become dissolved in precipitation. Nitric and hydrochloric acids may be similarly formed as a result of the widespread dispersal of sulfur and nitrogen oxides. All parts of the Great Lakes watershed are receiving precipitation which contains 5 to 40 times more acid than precipitation under natural conditions (Figure 2).

Global energy demands have increased exponentially for the past 50 years, and may continue to do so well into the next century (Figure 3 and 4). Without management controls, sulfur and nitrogen oxides may be expected to follow the same trends. In the absence of adequate controls, the current energy crisis, with its resulting return to coal as an energy source, seems certain to intensify the problem.

The problem in the Great Lakes Basin cannot be viewed as unconnected to the global problem of air contamination. Many countries may decide to use fuels higher in sulfur and other contaminants and there may not be assurance of adequate control measures within these countries. This problem on a global basis may be analogous to the nonpoint source problem with phosphorus in terms of control strategies.

Ecological Effects of Acid Precipitation

The acid in precipitation reacts with calcareous materials (such as limestone) in soils and rocks and dissolved bicarbonate in lakes. Initially these reactions neutralize the acid inputs, but in softwater lakes, such as those in Precambrian areas of the northern Great Lakes Basin (Figure 2), the amounts of neutralizing substances are so low that bicarbonate reserves are depleted quickly by acid precipitation. For example, it has been found that some lakes in the Haliburton-Muskoka area, which drain into Lakes Huron and Ontario, have lost 40% to 75% of their

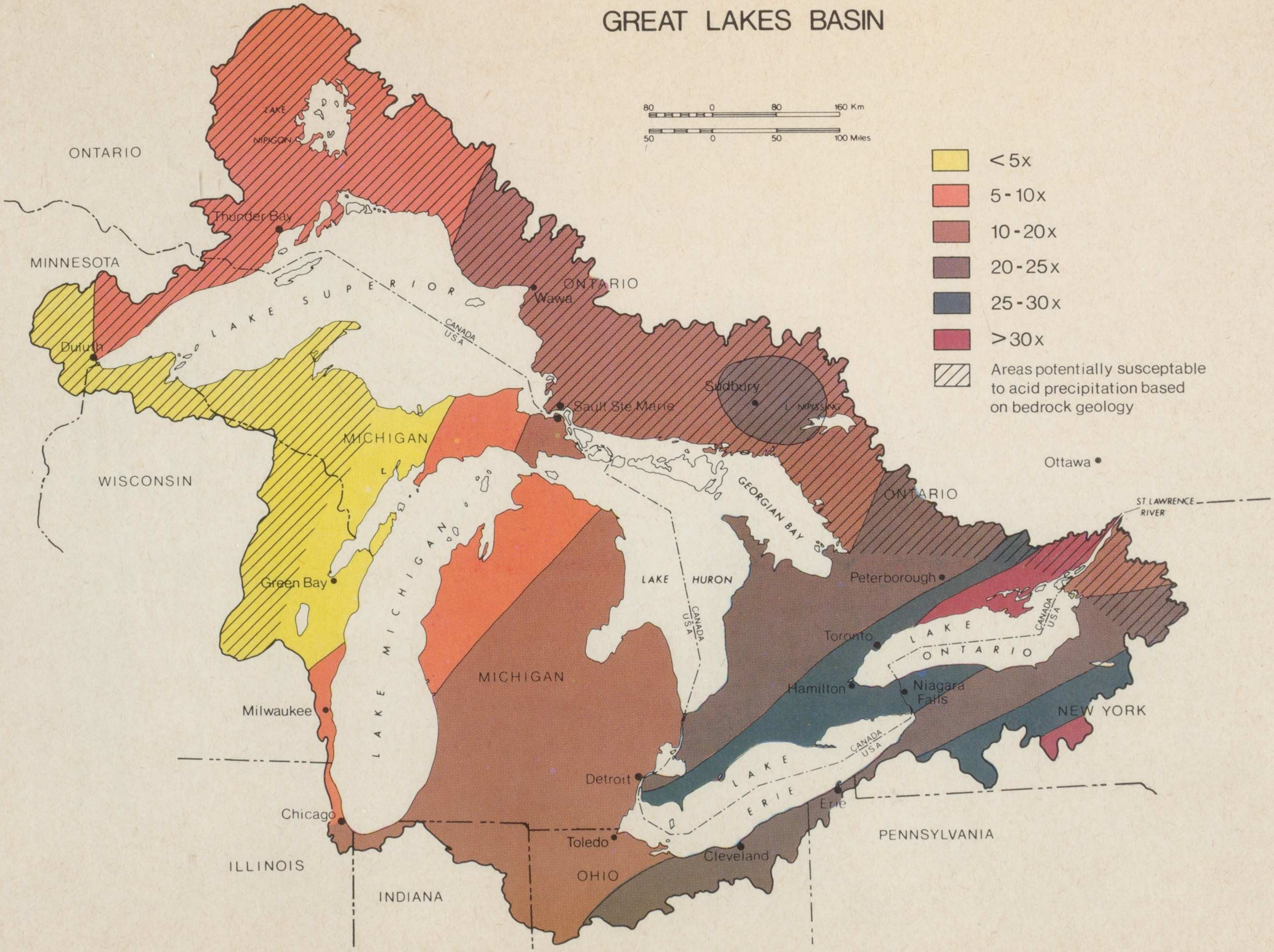


Fig. 2 INCREASED ACIDITY IN BULK PRECIPITATION OVER NATURAL CONCENTRATION (pH 5.7)

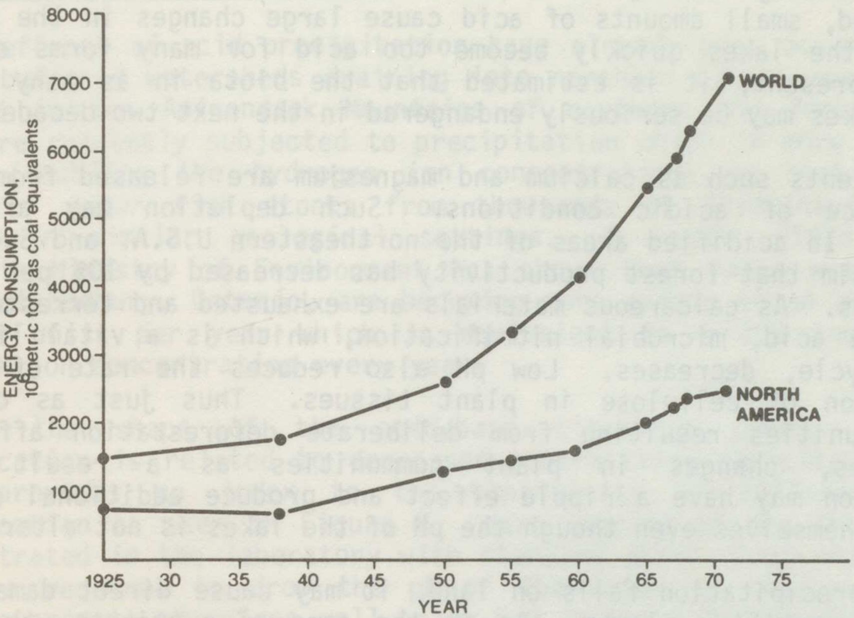


Fig. 3 ENERGY CONSUMPTION (COAL EQUIVALENTS) FOR THE PAST FIFTY YEARS, (BASED ON DATA FROM ENERGY AND CLIMATE, U.S. NATIONAL ACADEMY OF SCIENCE, 1977.)

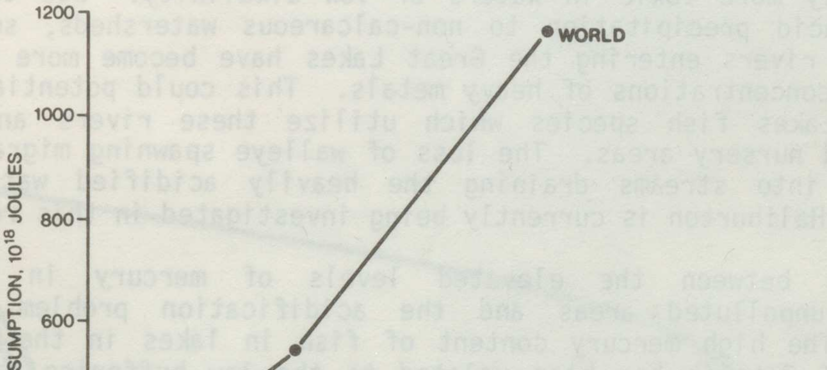


Fig. 4 PROJECTED ENERGY CONSUMPTION (JOULES) FOR THE NEXT FORTY FIVE YEARS. (BASED ON DATA FROM ENERGY AND CLIMATE, U.S. NATIONAL ACADEMY OF SCIENCE, 1977.)

acid neutralizing ability in a decade or less. Once buffering reserves are depleted, small amounts of acid cause large changes in the pH of the water and the lakes quickly become too acid for many forms of aquatic life. At present, it is estimated that the biota in as many as 50,000 Canadian lakes may be seriously endangered in the next two decades.

Vital nutrients such as calcium and magnesium are released from soils in the presence of acidic conditions. Such depletion may affect soil fertility. In acidified areas of the northeastern U.S.A. and Sweden, some workers claim that forest productivity has decreased by 10% per decade in recent years. As calcareous materials are exhausted and terrestrial soils become more acid, microbial nitrification, which is a vital link in the nitrogen cycle, decreases. Low pH also reduces the rate of microbial decomposition of cellulose in plant tissues. Thus just as changes in plant communities resulting from deliberate deforestation affected the Great Lakes, changes in plant communities as a result of acid precipitation may have a ripple effect and produce additional changes in the lakes themselves even though the pH of the lakes is not altered.

When acid precipitation falls on land, it may cause direct damage to the foliage of sensitive plants. As in the case of nutrients, the hydrogen ions may facilitate the release of toxic heavy metals such as mercury, copper, lead, nickel, aluminum and zinc bound to soils and lake sediments. The released heavy metals may then approach levels which affect aquatic organisms. Aluminum is of particular concern. Also metals are generally more toxic in waters of low alkalinity. Due to the high inputs of acid precipitation to non-calcareous watersheds, some of the streams and rivers entering the Great Lakes have become more acidic and carry high concentrations of heavy metals. This could potentially affect the Great Lakes fish species which utilize these rivers and bays as spawning and nursery areas. The loss of walleye spawning migrations from Lake Huron into streams draining the heavily acidified watersheds of Muskoka and Haliburton is currently being investigated in this regard.

Correlations between the elevated levels of mercury in fish from apparently unpolluted areas and the acidification problem have been reported. The high mercury content of fish in lakes in the Lake Huron Watershed of Ontario has been related to the low buffering capacity and therefore the low pH of these lakes. It has similarly been linked to the mercury content of fish in Cranberry Lake and Stillwater Reservoir. These low pH Adirondack lakes are located in the Oswegatchie and Black River Watersheds which flow into the international section of the St. Lawrence River and Lake Ontario respectively. Smallmouth bass greater than 30 cm length in these waters contain 1.3 to 2.5 ppm mercury.

Several explanations have been presented to account for the elevated mercury levels in fish from apparently unpolluted areas. The acidity may be causing naturally occurring mercury to leach from natural rock and soil formations. Mercury may also be entering the lakes with rain and snow as a result of emissions from the same sources of airborne acidity, e.g. coal burning. The low pH of the water may facilitate bacterial conversion of mercury into methyl mercury which is taken up by the fish.

Effects In the Great Lakes Basin

Severe effects of acid precipitation have already been documented in some poorly buffered watersheds draining into northern Lake Huron and Georgian Bay and in the Adirondack Mountains of northern New York State. Both areas are currently subjected to precipitation which is more than twice as acidic (doubling the hydrogen ion concentration) as that which caused losses of major fish stocks from thousands of Scandinavian lakes and streams in similar geological settings. A recent (1978) summary by Ontario's Ministry of Environment has shown that lakes within a 100 km radius of Sudbury, Ontario, are becoming more acidic at an average rate of 0.09 pH units per year which is equivalent to a 20% increase in the hydrogen ion concentration every year.

Due to the shape of the acid-base titration curve, the rate of acidification is related to decreased neutralizing capacity. A titration curve provides an index to the sensitivity of different waters to acidification as seen in Figure 5. Here samples of the lake waters have been titrated in the laboratory with standard acid. Only small amounts of acid are required to drop the pH of the water of Lumsden Lake in the LaCloche area to pH values well below 5.0 in which fish populations cannot survive. As can be seen from the titration curve, Glen Lake with a pH of 7.7 is well buffered.

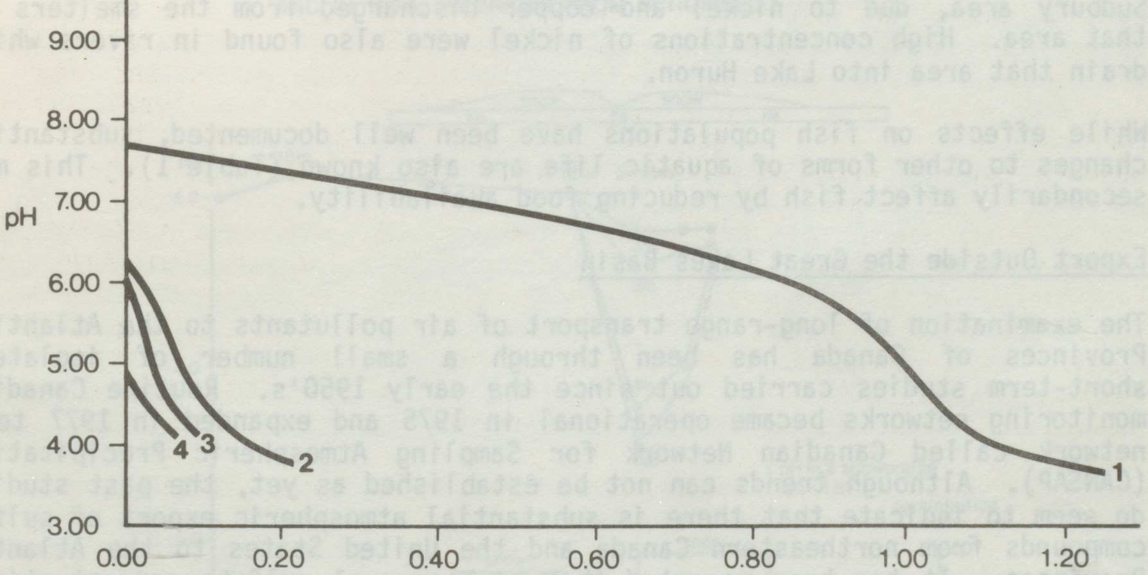


Fig. 5 TITRATION CURVES FOR 1) GLEN LAKE, A MODERATELY HARD WATER (ALKALINITY 0.98 MEQ. L^{-1}) LAKE ON PRECAMBRIAN SEDIMENTS; 2) AND 3) TWO OF THE PRECAMBRIAN SHIELD LAKES STUDIED IN HALIBURTON-MUSKOKA, RED CHALK AND CLEAR RESPECTIVELY, AND 4) LUMSDEN LAKE, AN ACIDIFIED LAKE IN THE LA CLOCHE AREA (BEAMISH AND VAN LOON 1977).

Few old records are available for the Haliburton-Muskoka area, but it seems likely that some of the lakes had already been severely affected a decade ago. The "Aurora trout" became extinct in the area in the 1950's and 1960's and in some cases, reproduction by salmonids is no longer possible. Lakes in the Haliburton-Muskoka area have concentrations of heavy metals which are much higher than in lakes within areas where precipitation is less acid.

In the Adirondack Mountains, fish stocks and pH values were assessed in the 1930's. A recent resurvey of the same lakes has shown that the lakes are now much more acidic, and that fish populations have have been severely depleted (Figure 6).

Areas which accumulate acidic components of precipitation for several months in the snowpack may suffer dramatic effects when the snowpack suddenly melts in spring. The sudden discharge of acidic water into lakes and streams (Figure 7) causes increases of up to 100 x in acidity. Changes in concentrations of major ion constituents in the Spanish River during 1977 spring runoff are shown in Figure 8. Alkalinity was decreased five fold and the normal pH of approximately 6.5 dropped below 5 for a short period. High concentrations of aluminum are also found in Adirondack runoff water when the acidic snowpack melts in the spring. The discharge of this acidic, aluminum-rich water into Adirondack lakes and streams is extremely toxic to brook trout and other aquatic organisms. Concentrations of available aluminum in the soils north of Georgian Bay have become high enough to hinder germination and seedling establishment for some forest species. Similar problems have been encountered in the Sudbury area, due to nickel and copper discharged from the smelters in that area. High concentrations of nickel were also found in rivers which drain that area into Lake Huron.

While effects on fish populations have been well documented, substantial changes to other forms of aquatic life are also known (Table 1). This may secondarily affect fish by reducing food availability.

Export Outside the Great Lakes Basin

The examination of long-range transport of air pollutants to the Atlantic Provinces of Canada has been through a small number of isolated, short-term studies carried out since the early 1950's. Routine Canadian monitoring networks became operational in 1975 and expanded in 1977 to a network called Canadian Network for Sampling Atmospheric Precipitation (CANSAP). Although trends can not be established as yet, the past studies do seem to indicate that there is substantial atmospheric export of sulfur compounds from northeastern Canada and the United States to the Atlantic Provinces. It has been reported that high aerosol sulfate concentrations in the Great Lakes area were, in two days time, transported to Nova Scotia. The elevated sulfate levels comprised about 50% of the particulate matter captured by the sampler. Examination of concurrent surface weather maps indicated that the high concentrations of sulfates were located in the warm air south of a frontal system, and appeared to move along with the system.

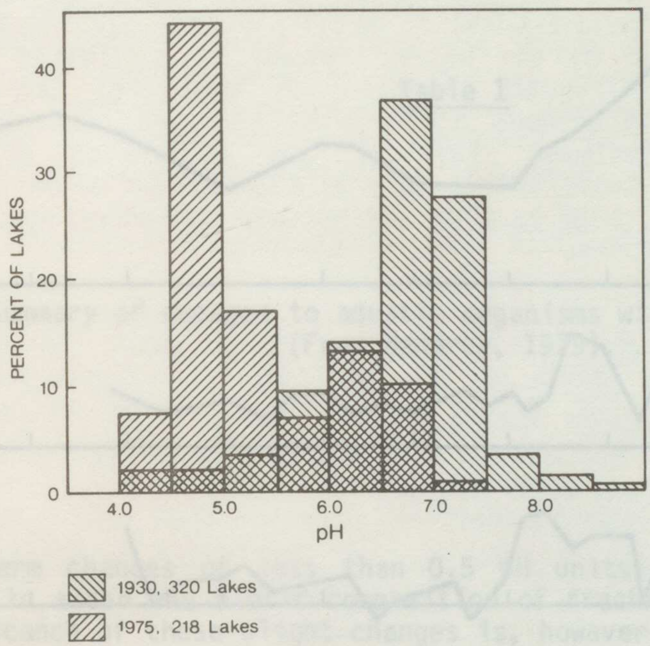


Fig. 6 FREQUENCY DISTRIBUTION OF pH IN LAKES IN THE ADIRONDACK MOUNTAINS, NEW YORK, IN THE 1930's AND IN 1975. (REDRAWN FROM SCHOFIELD.)

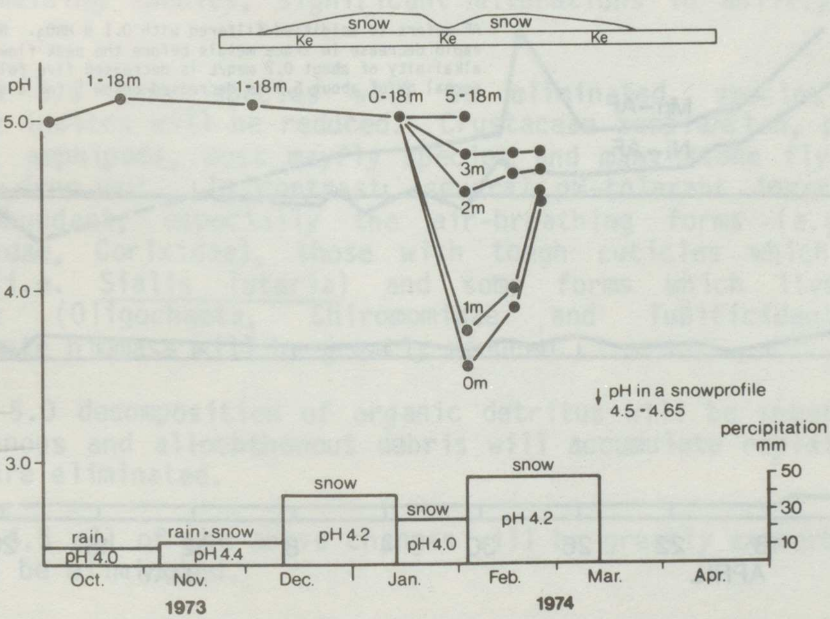


Fig. 7 pH–VARIATION DURING WINTER 1973–1974 (FIELD MEASUREMENT) IN L. STENSJÖN IN VÄRMLAND. NOTE THE pH AND AMOUNT OF PRECIPITATION, AND pH IN SNOW PROFILES. (FROM HULTBURG, 1977).

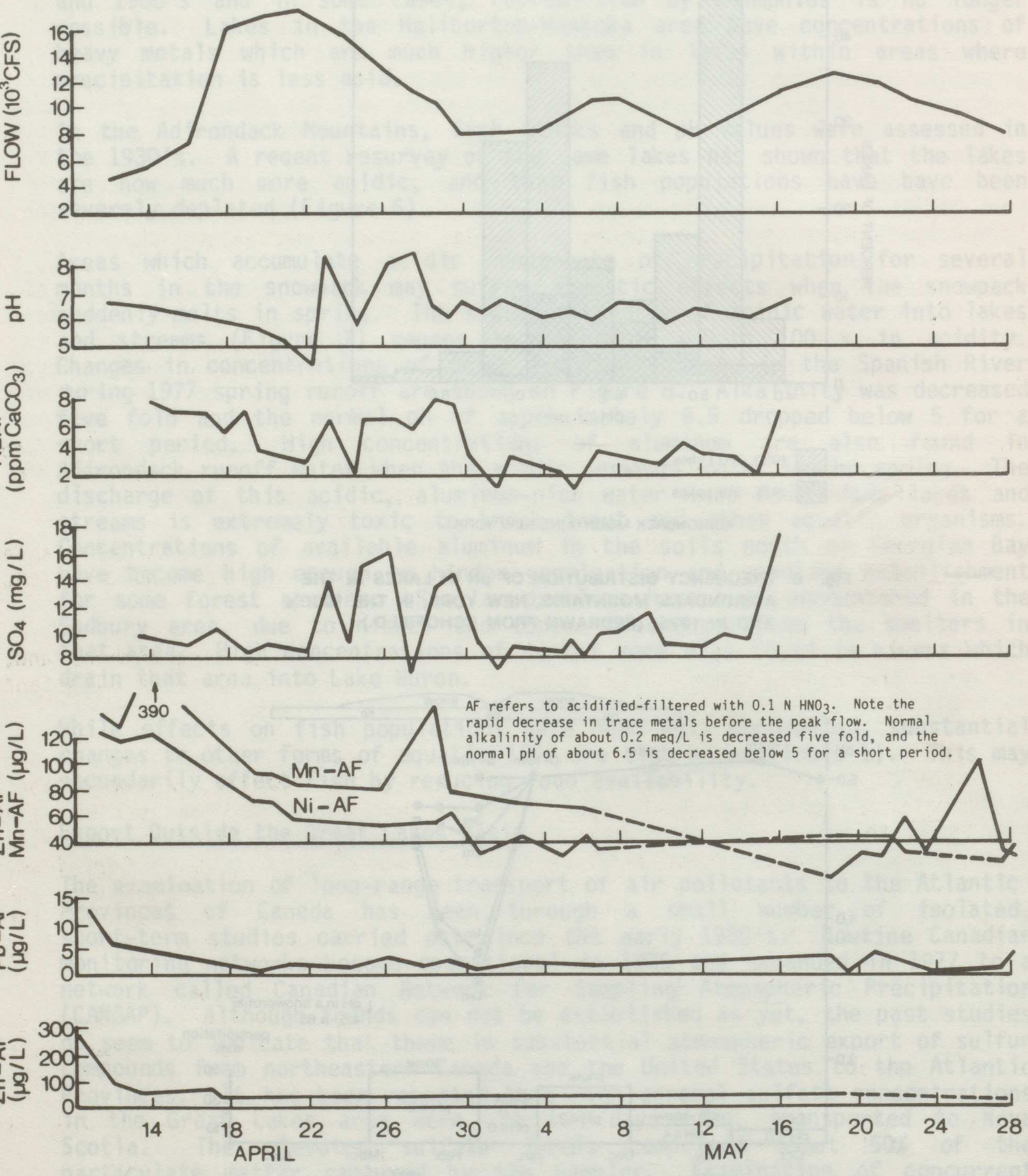


Fig. 8 CHANGES IN CONCENTRATIONS OF MAJOR CONSTITUENTS IN THE SPANISH RIVER DURING SPRING RUNOFF. 1977.

Table 1

Summary of damages to aquatic organisms with decreasing pH.
(From Hendrey, 1979).

A. Long term changes of less than 0.5 pH units in the range 8.0-6.0 are likely to alter the biotic composition of freshwaters to some degree. The significance of these slight changes is, however, not great.

B. A decrease of 0.5-1.0 pH units in the range 8.0-6.0 may cause detectable alterations in community composition. Productivity of competing organisms will vary. Some species will be eliminated.

C. Decreasing pH from 6.0-5.5 will cause a reduction in species numbers and, among remaining species, significant alterations in ability to withstand stress.

D. Below pH 5.5 many species will be eliminated, species numbers and diversity indices will be reduced. Crustacean zooplankton, phytoplankton, molluscs, amphipods, most mayfly species and many stone fly species will begin to drop out. In contrast, several pH-tolerant invertebrates will become abundant, especially the air-breathing forms (e.g. Gyrinidae, Notonectidae, Corixidae), those with tough cuticles which prevent ion losses (i.e. Sialis lutaria) and some forms which live within the sediments (Oligochaeta, Chiromomidae and Tubificidae). Overall, invertebrate biomass will be greatly reduced.

E. Below pH 5.0 decomposition of organic detritus will be severely impaired. Autochthonous and allochthonous debris will accumulate rapidly. Most fish species are eliminated.

F. Below pH 4.5 all of the above changes will be greatly exacerbated, and all fish will be eliminated.

Human Health and Acid Precipitation

Acid precipitation may also be detrimental to the health of residents in the Great Lakes Basin. Acidic water in metal plumbing may increase copper and lead concentrations in the water. Based on a limited number of measurements from the Adirondack Mountains of New York, natural spring waters from acidified watersheds are showing elevated concentrations of lead, copper, and aluminum. Further, the occurrence of elevated concentrations of other toxic metals such as cadmium and mercury cannot be ruled out. For example, high cadmium and mercury concentrations have been found in Scandinavian waters.

There is a potential for metal toxemia from the consumption of acidified water. Although the acidification of drinking water in Bennington, Vermont led to elevated levels of lead and copper, no valid reports have been found indicating the extent of illness caused by such metal concentrations.

Energy Consumption and Acid Precipitation

As human demands for energy have increased at an exponential rate, so has our output of the sulfur and nitrogen oxides which cause acid precipitation. As Figure 3 shows, demand for energy is now increasing exponentially a trend which could continue or increase further in the next 50 years. The recent U.S. decision to use coal for a higher proportion of its energy requirements in the next few decades can only aggravate the problem unless SO_x and NO_x are controlled.

Another major source of SO_x is from sulfide minerals which are smelted to produce a number of important metals. For example, the nickel rich iron sulfide entering the smelters at Sudbury, Ontario contains about 40% sulfur by weight. Unless removed prior to smelting, all of the sulfur is converted to SO_2. Technology for removing the sulfur from the ore has been developed and some sulfur is currently removed and converted to sulfuric acid. Expansion of the facility to remove more sulfur has been inhibited by an inadequate market for sulfuric acid. It is, however, noteworthy that Minnesota's copper-nickel project will require 99% SO_2 removal from smelters installed in that area.

Sulfur oxide emissions can be reduced in a number of ways. Where the source is fossil fuels, efforts can be made to burn low-sulfur fuels. At present, in eastern North America low sulfur coal is usually expensive and not as available as high sulfur coal, so that the latter is burned in order to minimize the direct cost to the rate payer.

"Scrubbing" of sulfur from stack effluents is also possible. Once again, the technology is costly, and reports on reliability vary. Desulfurization of coal prior to combustion is still in the experimental stages.

An obvious choice is to reconsider major methods of producing electricity, and/or reduce the use of electrical power. *The public has to be aware of the many hazards of coal burning, beyond acid precipitation which include the direct damage caused by SO_2 and stack emissions of radionuclides, which exceed amounts released by nuclear plants, toxic heavy metals and fly ash. There is an obvious need for assessment of relative risks and true costs of various energy alternatives, including energy conservation, and a wide-scale public information program.*

Information Needed to Improve Our Understanding of the Acid Precipitation Problem

The extent of damage to date and susceptibility to future damage from acid precipitation is not completely known. One of the reasons for this is that we are not in a steady-state situation. The rate of addition of sulfur and nitrogen oxide to air has been increasing exponentially, hence past and present conditions do not reflect what the situation will be in the future. The problem is a creeping one, now well recognized in water resources. The deterioration of forests must be presumed to exist. Several existing techniques must be applied to the problem in order to assess the current vulnerability and previous damage to lakes caused by acid precipitation.

Particularly valuable might be a compilation of historical data sets for pH, conductivity, alkalinity and other parameters related to acidification from several research stations in the Great Lakes Basin. For example, chemical data for more than 400 lakes were collected at the Trout Lake Station in northern Wisconsin in the 1920's and 1930's. Several other large data sets in the U.S. and Canada are known to extend back to the 1920's and 1930's. Careful resurveys of lakes for which historical information is available may provide an indication of the degree of deterioration of lakes and streams in different regions and geological settings.

For the many areas where historical data do not exist, paleolimnological methods may be brought to bear. Specific assemblages of diatoms grow at different pH conditions, including any species which are well preserved in lake sediments. By enumerating the diatoms in strata of dated sediments, it is possible to assess the rate at which acidification has proceeded. Although developmental work is necessary it is probable that many other groups of organisms, such as chironomids and zooplankton, exhibit acidophilic "indicator communities" which could be similarly used. The assessment of lichen species and growth is another sensitive indicator which has not been widely applied in North America.

At present, we do not know the rate at which acid precipitation is acidifying many of the water bodies. In addition to bicarbonate dissolved in the water, calcareous sediments and biological processes such as photosynthesis and sulfate reduction may act as neutralizing agents. Mass balance studies are needed for acid, sulfate and calcium, similar to those for phosphorus which have provided the basis for eutrophication management models.

The synergistic effects of acid and/or toxic substances, such as metals and PCBs, on natural ecosystems, require further study. Limited data are available for those substances in the very soft waters which characterize areas susceptible to acid precipitation.

The Board recognizes that informational studies needed to address the question of acid precipitation control, must be conducted in a coordinated manner in order that timely and efficient utilization of laboratory facilities, manpower and capital expenditures are achieved. To this end, the Board, by letter dated November 6, 1978, requested that the Commission support a National Atmospheric Deposition Program proposal now before the U.S. Council on Environmental Quality (CEQ). The general outline of this research program is given in Table 2. Detailed descriptions of the research recommendations are given in the Council's report.

Ameliorative and Corrective Measures

Based upon the history of phosphorus control, it seems likely that the acid precipitation problem will be solved very slowly and that the biota of a large number of lakes and streams will be irrecoverably altered, perhaps for geological time. Amelioration measures must therefore occupy a prominent spot in research priorities. In Scandinavia and in Ontario, liming of affected lakes has proved moderately successful, although costly (approximately $50 per acre). The effect of a single liming treatment may last for only several years depending on the lake. Costs and efficiency might be improved by further methodological work. *While it will not be possible to lime the vast areas of the Great Lakes drainage which are affected by acid precipitation, liming may be a means of maintaining natural biota in selected sanctuary areas.*

The only effective means of reducing the acid precipitation problem is by greatly reducing emissions of sulfur and nitrogen oxides. Because severe effects are already occurring, and are expected to increase greatly in the next two decades, swift, decisive and widespread action is required. Pollution abatement policy to date in many areas has been to build tall stacks to disperse pollutants and eliminate local problems. This policy has been partly responsible for the widespread nature of the acid precipitation problem.

The major stumbling block to implementation of measures to control any pollutant is usually an economic and political one. While the concept of looking at sources and effects of pollutants on a broader ecosystem basis is gaining widespread acceptance in the Great Lakes Basin, it has not yet been expanded to include economic matters. It seems likely that utilities and industries which are attempting to minimize direct costs of energy or materials to consumers may actually be inflicting much greater "hidden costs" on the public at large.

While no economic cost figures of the impact due to acid precipitation are available which pertain directly to the Great Lakes Basin, it is worth noting some costs from other studies. In a recent report, the U.S.

Table 2

RECOMMENDED RESEARCH PROGRAM
(From CEQ, 1978)

Measurement of Atmospheric Deposition

1. Determine spatial and temporal variations in atmospheric deposition;
2. Determine nature of acid inputs to ecosystems;
3. Develop improved methods for measurement of dry deposition;
4. Determine mesoscale variability of atmospheric deposition;
5. Determine magnitude of atmospheric deposition of trace substances. (e.g., metals and organics)

Calibrated Watershed Program
(Analysis of chemical linkages between atmospheric/terrestrial/aquatic systems).

1. Chemical mass balance of elements;
2. Mobilization of nutrients and toxic substances in soils;
3. Experimental manipulation of ecosystems.

Biological Effects Program
(Analysis of effects on physiological functions, organisms and ecosystems).

1. Agriculture;
2. Forestry;
3. Wetlands and aquatic ecosystems.

Economic Assessment and Criteria Development

1. Estimate of current losses;
2. Identification of vulnerable organisms, soils and ecosystems;
3. Criteria for action.

President's Council on Environmental Quality estimated health costs attributable to SO_2 at $1.7 billion per year. Architectural damage was estimated to be $2 billion per year. There is also one estimate that acid precipitation causes approximately 50% of the man-made corrosion of cars. Recent Canadian studies place the economic value of sport and commercial fisheries in the acid-sensitive Precambrian Shield at over $600 million annually. No economic estimates are available for damage to forests or agricultural products, although in acidified areas of Scandinavia and the northeastern U.S.A., forest productivity may have decreased.

Air Pollution Control Technology Related to Acid Precipitation

SO_2 Control Technology - United States

Available SO_2 control technology options currently available consist of: using low sulfur coal, physical coal cleaning and flue gas desulfurization. Emerging control technologies include: coal gasification, coal liquefaction and fluidized bed combustion. The low sulfur coal option is the simplest approach but it has certain limitations. Low sulfur coal is found in the West far from the major power producing facilities in the East. Transportation costs and potential disruption of local Eastern economies based on high (above 3.5%) sulfur coal production are factors. If more stringent New Source Performance Standards (NSPS) for SO_2 emissions are established this option may be eliminated.

Coal cleaning is based on the physical separation of inorganic pyritic sulfur from the coal due to specific gravity differences. Removal efficiencies up to 80% of the pyritic sulfur are possible. This corresponds to an overall removal of sulfur content of 16% to 64% depending of the character of the coal. This option has a severe limitation in that only 13.5% of the U.S. coal reserves are suitable for cleaning to meet the current NSPS requirements. The use of coal with a lower sulfur content in existing power plants may also have the consequences of lower operating capacity and higher particulate emissions.

There are a variety of flue gas desulfurization (FGD) processes that are either available or under development. Significant demonstration and development efforts by the private sector and public sector are being conducted and the status of alternatives is changing rapidly.

Lime or limestone sludge scrubbing are the most prevalent systems in the U.S. They have been commercially demonstrated with low sulfur coal (<1%), at 115 Mw and 170 Mw facilities respectively, and achieve sulfur removal in excess of 90% removal. Lime scrubbing of medium and high-sulfur coal has also been demonstrated at the 100 Mw capacity with 90% reduction reported. One of the disadvantages of this technology is the large amount of waste sludge products that are difficult to handle; primarily unoxidized calcium sulfite and calcium sulfate. Ultimate disposal options include storage in underdrained ponds, and chemical fixation to permit use in landfills, mine reclamation areas, or possible conversion to gypsum. Coal-fired power plants, without FGD will cost about \$500/Kw in capital costs and 30 mills/kwh in operating costs. Lime scrubbing to a new power plant, burning high-sulfur coal, can add from \$60-\$130/Kw in capital costs and 3-5 mills/kwh in operating costs which adds 10 to 15% to the cost of power generation from coal. Flue gas desulfurization costs are sensitive to the sulfur content of the coal used. Various combinations of low-sulfur coal blending, or coal cleaning with FGD may be desirable.

A smaller number of operating units in the U.S. use the sodium sulfite (Wellman-Lord SO_2 recovery process) or the magnesium oxide process. Other FGD technologies of commercial interest which are operating in Japan include: double alkali/sludge, limestone/gypsum, lime/gypsum, double alkali/gypsum, and dilute sulfuric acid/gypsum. The emerging technologies of coal gasification, liquefaction and fluidized bed combusion are not likely to be of commercial significance until after 1985.

NO_2 Control Technology - United States

For the U.S., fuel combustion from stationary sources emit about 50% of the atmospheric nitrogen oxides. Electric power generating emits 24% of the total. Transportation is the second largest contributing source at 35% of the total. Like SO_2, much (56%) of the total U.S. emissions of NO_2 are found in the Northeast.

Control technology options for NO_2 from stationary sources basically relate to lowering the oxygen levels and/or maximum temperatures in the flame zone through techniques such as: low-excess-air firing, staged combustion, flue-gas recirculation, water injection and reduced air preheat. The latter two options may have unacceptable penalties in thermal efficiency. Nitrogen oxide reductions of 37% to 60% are possible through these techniques.

SO_2 Control Technology - Canada

The control technologies for sulfur dioxide and nitrogen oxides emissions from stationary source in the United States, summarized above apply equally in Canada.

Whereas 75% to 80% of the sulfur-dioxide emissions in the U.S. are from stationary-fuel combustion sources, about 75% of the total emitted in Canada originates from industrial sources, indicating clearly that Canada has a different SO_2 control problem as shown in the Table 3. The largest emitter of sulfur dioxide in Canada is the primary nickel and copper industry which accounts for about half of the total SO_2 emitted annually.

Available SO_2 control technology for the primary nickel and copper industry consists of:

1) Use of sulfuric acid plants (single or double contact).

2) Production of liquid SO_2.

3) Production of elemental sulfur.

4) Tall gas scrubbing technologies, e.g., double alkali, limestone, and MgO.

5) Process change.

Table 3

Nationwide Air Pollutant Emissions - Sulfur Dioxide

Category	Canada	United States	
	(1974)	(1974)	(1977)
Nationwide Emissions	6.2×10^6 tons	28.4×10^6m tons	22.4×10^6m tons
Stationary Fuel Combustion	23.3%	77.8%	81.7%
Industrial	75.[illegible]%	19.7%	15.3%

The most common technology is that of contact sulfuric acid plants. The SO_2 strength in the gas stream ranges from 4% to 12% for normal operation. Many of the existing plants are not suitable for this technology since the SO_2 concentration in most of the gas streams is too dilute for the acid plants. Major limiting factors are the cost of the acid plants and support facilities, and the limited market for the sulfuric acid product. The sulfuric acid will usually have to be sold at a loss and, for large quantities, this can involve governmental trade restrictions, such as dumping provisions, which limit the quantities which can be marketed.

Liquid SO_2 requires high SO_2 strengths (generally 60% or higher) and thus is limited to a very few process units. The market for liquid SO_2 is also very limited.

No elemental sulfur plants are operating due to the extremely high operating costs and cannot be considered as a viable technology under present conditions.

Tall gas scrubbing technologies have only been utilized under special conditions where extremely low SO_2 emissions are required, such as Japan.

Process change is being utilized in many plants, almost always in conjunction with acid plants. New production processes are available which have flue gas streams containing sufficient SO_2 concentration for treatment in acid plants. In a few, small and localized cases, hydrometallurgical production processes can be utilized with no SO_2 emissions. A limiting factor is the high cost of production process change.

Although utilization of the SO_2 abatement technology available may not be justified from the perspective of a specific industry sector, it may be necessary to impose the most cost-effective control technology for SO_2 emissions to do our share to ameliorate the environmental effects resulting from acid rain in North America.

Regulatory Options

The United States Clean Air Act as amended in 1970, 1974 and 1977 provides a variety of mechanisms to control air pollution. Section 108 of the National Ambient Air Quality Standards (NAAQS) identifies a maximum ambient pollutant concentration for a specified period of time based on public health considerations (primary standard) or public welfare considerations (secondary standard). National Ambient Air Quality Standards for sulfur and nitrogen oxides are shown in Table 4.

Table 4

U.S. Ambient Air Quality Standards

POLLUTANT	AVERAGING TIME	PRIMARY STANDARDS	SECONDARY STANDARDS
Sulfur Oxides	Annual (Arithmetic mean)	80 μg/m^3	-
	24-hour	365 μg/m^3	-
	3-hour	-	1300 μg/m^3
NO_2	Annual (Arithmetic mean)	100 μg/m^3	100 μg/m^3

Many existing power plants (pre August 1971) in the 247 air quality regions will have to limit their emissions to meet the ambient air quality standards as part of the State Implementation Plans required by the Act.

New Source Performance Standards (Section 111) of the Clean Air Act based on demonstrated and best available control technology (including cost considerations) limit emissions of public health or welfare significance from new or modified sources. New source performance standards have been established for steam generators (SO_2, NO_2, TSP), sulfuric acid plants (SO_2), nitric acid plants (NO_2) and petroleum refineries. A new source meeting the NSPS emission standards may not be operated if it would violate the ambient air quality standards. The current New Source Performance Standard limits the emission of SO_2 from power plants to 1.2

lb/million BTU when solid fuels are burned. Such a restriction requires about 70% SO_2 control for a 3% sulfur coal. The NSPS for coal-fired power plants are currently being reevaluated.

Mobile source emission reductions of 90% from 1970 levels are required for CO, HC, and NO_x under Section 202 of the 1970 Act.

Future trends of sulfur oxide and nitrogen oxide emissions vary considerably. One report indicates that, under the present regulatory structure, power plant SO_2 emissions will increase from 23 million tons per year in 1976 to 34 million tons per year by the year 2000. Constant to slightly decreasing emissions of SO_x of about 20×10^6 tons/yr and an increase of NO_x emissions from 15×10^6 tons/yr to 18×10^6 tons/yr for the years 1976 to 1980 have also been predicted. These data are for a 24-state area in the Northeastern United States. Projections of future emission levels are difficult to make because of the many assumptions relative to projected growth in combustion sources, fuel use patterns, levels of NSPS in future regulations and the degree of compliance to the regulatory program.

Several aspects of the Clean Air Act Amendments as they relate to the acid precipitation phenomena are worth noting. The standards are national while the problem is regional in character. Ambient air quality standards can be achieved by tall stacks which contribute to long range dispersion without really resolving the problems. Any change in the existing ambient standards deemed necessary to reflect the consequences of acid precipitation will have to be based on scientifically sound, quantifiable data demonstrating cause and effect relationships from emissions to adverse impacts on the public health or welfare.

The Province of Ontario's ambient air quality criterion for SO_2 set out under the regulations of the Province's Environmental Protection Act of 1971 is 690, 270 and 55 $\mu g/m^3$ for one hr., 24-hr. and 1 year average respectively. The ambient criterion for NO_2 is 400 and 200 $\mu g/m^3$ for the 1 hr. and 24-hr. averages respectively. The Ontario ambient air quality criteria for SO_2 and NO_2 apply to both existing and new sources.

Legislation Governing International Air Pollution

The Great Lakes Science Advisory Board is aware of the views expressed by the Commission's International Air Pollution Advisory Board regarding legislation governing international air pollution. As stated by the Air Pollution Advisory Board:

"The two countries have specific legislation aimed at controlling international air pollution. To become operative, the U.S. legislation requires reciprocal arrangements in the foreign country affected whereas the Canadian legislation is dependent for its effectiveness on the existence of an international obligation. Because of this interdependence, neither section quoted can be used unilaterally for the purposes stated. Moreover, it is apparent from a review of existing transboundary air pollution problems that clear principles governing the obligation of one country to another in a given situation are lacking. Accordingly, the Board recommends that this matter be further examined with a view to identifying appropriate legal mechanisms and principles."

The Great Lakes Science Advisory Board supports the International Air Pollution Advisory Board in its recommendation to the Commission.

The Science Advisory Board acknowledges the activities recently initiated between Governments relevant to transboundary air quality problems. Particularly noteworthy is the formation of a U.S. - Canadian Research Consultation Group on the Long Range Transport of Air Pollutants and the implementation of diplomatic talks on an Air Treaty.

<u>What's Needed for the Great Lakes Ecosystem</u>

An integrated acid precipitation program for the Great Lakes Basin is urgently required. The required program must be extremely diverse, with scientific, economic, educational and political components.

Detailed inventories must be developed for the susceptibility of different areas of the Great Lakes Basin. Where possible, existing data must be compiled to allow the assessment of damage to date. When coupled with detailed studies of the rates of deposition, it should be possible to evaluate the rate of deterioration of natural resources. A proper U.S. Canada study of the transboundary movement of pollutants is also required.

In order to promote rapid decision making, a widespread public education program on risks of acid precipitation, a thorough economic analysis of the problem, and studies of the comparative human and ecological risks of various energy alternatives should be undertaken as soon as possible. Every effort should be made to overcome the problems of "piecemeal" legislation which are sure to confound the control of emissions, many of which are in well-buffered areas where the immediate effects of acid precipitation will be negligible.

In light of these considerations, the Science Advisory Board recommends that the International Joint Commission immediately implement, as specified in Article VII(6) of the 1978 Great Lakes Water Quality Agreement, liaison among institutions established under the 1909 Boundary Waters Treaty, appropriate U.S. and Canadian agencies, and international organizations which address concerns relevant to the Great Lakes Basin Ecosystem to ascertain and ensure that all facets and concerns of the Great Lakes Basin Ecosystem, as outlined in this report, are adequatley considered. Particular emphasis on the problems associated with long range transport of airborne pollutants should be given high priority. Further, the Board recommends that the Parties to the Great Lakes Water Quality Board be encouraged to formulate a reference within the context of an ecosystem approach on the causes, effects and measures for the control of long range transport of airborne polutants with special attention to acid rain. Such action will serve to accelerate efforts to develop necessary information for firm rapid action.

B. Toxic Substance Control

Immediately following the signing of the 1972 Agreement, the Parties concentrated part of their efforts on the abatement and control of toxic substances listed under categories such as: "mercury and other toxic heavy metals"; "toxic persistent organic contaminants"; and "pest control products". The Parties were to develop specific water quality objectives for a number of substances including "organic chemicals". A Committee of the Research Advisory Board aided in this effort by providing scientific documentation to support each of the specific water quality objectives. Approximately 45 specific water quality objectives were derived, of which 27 were formally transmitted to governments by the IJC. Subsequently, surveillance and remedial program efforts were directed towards the assurance that the Great Lakes waters were within the defined objectives.

In the case of "organic compounds", objectives were derived for specific compounds which had been previously identified in the Great Lakes Basin. However, new compounds were being continually and frequently identified. The Board, therefore, foresaw the need to develop "predictive techniques" to identify potential contaminants before they became manifested throughout the Great Lakes.

In the 1977 and 1978 Annual Reports we described our efforts to develop a computer data base which would help forecast those organic chemicals manufactured or used in the Great Lakes Basin having the potential to persist and bioaccumulate. If such compounds are found to be released within our Ecosystem, testing may be needed to evaluate the potential hazard associated with the presence of the compounds. Since January 1979, the computer data base has been operational and accessible by use of remote terminals. Recently, the data base was utilized to identify halogenated organic compounds which are manufactured in the Great Lakes Basin and have a bioaccumulation potential of concern. The list of identified compounds was distributed to various analysts for evaluation. Confirmation of a compound within the Great Lakes does not necessarily imply a need for immediate concern. It does, however, necessitate evaluation with regard to properties such as toxicity. If additional evaluation indicates a compound is of concern, immediate steps will have to be recommended to minimize or prevent its release to the environment.

The Science Advisory Board's efforts to develop "predictive capability" are but one of many to prevent future manifestation of potential environmental hazards. For example, at the Research Advisory Board's

"1975 Symposium on Structure-Activity Correlations in Studies of Toxicity and Bioconcentration with Aquatic Organisms" researchers from several private industries described their efforts to devise systematic procedures to evaluate the effects to aquatic organisms of new materials prior to their commercialization. A listing of several other current hazardous substance evaluation efforts is shown in Table 5.

Table 5

Efforts Underway
For the Evaluation of
The Effects of Chemical Substances in the Ecosystem

Sponsor or Group	Scope of Efforts
Toxic Substances Control Act Interagency Testing Committee - members from CEQ*, Commerce, EPA, NSF, NIEHS, NIOSH, NCI and OSHA and non-voting members from Defense, FDA, Interior and CPSC.	Develop and use methodology to identify and recommend to the Administrator of the Environmental Protection Agency those chemical substances and mixtures which should be tested to determine their hazards to human health and the environment.
Interagency Regulatory Liaison Group - members from FDA, OSHA, EPA and CPSC.	Coordinate among the member groups - testing, risk assessment, regulatory actions, research, information exchange, public education, epidemiology and compliance.
Joint Dept. of the Environment/ National Health and Welfare Committee on Environmental Contaminants.	Identify and evaluate chemical substances used in Canada which may require appropriate control legislation.
National Science Foundation Program on Chemical Threats to Man and the Environment.	Support of research relevant to the prediction, identification, characterization and control of hazards resulting from chemical compounds in the environment. This research complements the efforts of other agencies by attempting to apply recent discoveries in the basic sciences to current problems.
United Nations Environment Programme (UNEP) - International Registry of Potentially Toxic Chemicals (IRPTC).	Objectives include: to facilitate access on a global basis to scientific and administrative data concerning potentially toxic and other environmentally significant chemical substances; to

	encourage international cooperation in determining the impact of chemicals on man and the environment; to provide secretariat aid for the operation of the early warning capability being developed within relevant sections of the Programme.
Organization for Economic Cooperation and Development (OECD)	Develop a common approach for extended control of chemicals in member countries and harmonization of requirements. Chemicals Testing Program consists of six expert groups on: physical chemistry; eco-toxicology; degradation-accumulation; long term toxicology; short term toxicology; and, step-sequence testing.
European Economic Community	Develop procedures for systematic review of new and existing commercial chemicals. Development of a data bank on 5000 compounds produced in large quantities and liable to have harmful effects on human beings, animals or the environment.
North Atlantic Treaty Organization (NATO)	Five Special Science Programs are designated to address: Air-Sea Interaction; Eco-Sciences; Human Factors; Marine Sciences, and Systems Sciences. The Eco-Sciences Programme is directed to further the knowledge of the ecosystems and their modifications, and has for example, sponsored workshops and studies on: "Eco-toxicology of persistent chemicals" and "species differences in metabolic actuation of environmental toxicants."
American Society for Testing and Materials, Section E35.2.02 (Membership represents industry, government, academic institutions and consulting firms).	Develop protocols for obtaining information needed to predict possible behavior in the environment of new and expanded-use chemicals.
IJC Committee on the Assessment of Human Health Effects of Great Lakes Water Quality	Evaluate the potential health effects of 400 compounds identified to be present in the Great Lakes Basin Ecosystem.

Great Lakes Basin Commission	Develop a strategic plan for toxic substances control for its "Great Lakes Basin Plan". Part of the effort reviews U.S. federal and state control policies, laws and programs.
Great Lakes Basin Commission Standing Committee on Research and Development	Sponsor workshops on: toxic substances modelling; risk perspectives on toxic substances of concern in the Great Lakes system; recovery time from toxic substances pollution in the Great Lakes; and monitoring of "toxics."
Great Lakes Water Quality Board	Sponsor workshops to review existing procedures for evaluating hazardous substances; review early warning procedures; and, assessment of data gathering capabilities.

*NOTE:

CEQ - Council of Environmental Quality
CPSC - U.S. Consumer Product Safety Commission
EPA - Environmental Protection Agency
FDA - Food and Drug Administration
NCI - National Cancer Institute
NIEHS - National Institute of Environmental Health Sciences
NIOSH - National Institute for Occupational Safety & Health
NSF - National Science Foundation
OSHA - Occupational Safety and Health Administration

Table 5 shows that several coordinated multi-national and multi-agency efforts are underway and directed towards the evaluation of chemical substances.

Notable are the efforts of OECD and UNEP. Reference to such efforts for application within the Great Lakes Basin appears to be minimal. The Board recommends that future hazard assessment efforts in the Great Lakes Basin be carried out in the context of the identified multi-agency and multi-national efforts described in Table 5.

The related research programs of the participants to the programs outlined in Table 5 are significant in magnitude. Table 6 illustrates some of the resources expended for programs by agencies within the U.S. and Canada. There is an equally large effort at universities, independent research organizations and not least, private industries. These are not shown in the table.

Table 6

Examples of Ongoing U.S. and Canadian Programs
Directed Towards the Evaluation of Chemical Substances

Program	Project Title/Scope	FY 1978-79 ($)	Sponsor
Health and Ecological Effects Program	Characterization and Testing of Water and Hazardous Substances	1,260,000 (Extramural)	U.S EPA
	Water Quality Health Effects Development of Criteria for Recreational and Shellfish Growing Waters	360,000 (Extramural)	U.S. EPA
	Multi-Route Exposures and Their Effects: Determination of Health Implication of Substances Used as Pesticides	1,923,000 (Extramural)	U.S. EPA
	Identification of Adverse Health Effects Due to Exposure to Toxic Substances	380,000 (Extramural)	U.S. EPA
	Freshwater Ecological Processes and Effects	2,088,000 (Extramural)	U.S. EPA
Contaminants in Inland Waters	Research and monitoring of wildlife, soil, long range transport, airborne pollutants, forest spraying	2,610,000	Environmental Management Service-Canada
Environmental Toxicology	-	487,000	Great Lakes Biolimnology Laboratory - Fisheries and Oceans Canada
Toxic Substances	Health Hazard Evaluation of Environmental Contaminants	978,000	Health and Welfare Canada
Hazardous Organic Substances in the Environment	-	476,500	Ontario Min. of Environment

Although the list is only a representative sample, the magnitude of the funds expended indicates the high concern governments have on assessing the potential effects of man-made chemicals in the environment.

The Board intends to continue to review and assess such efforts. Until such efforts are completed, the Board for now, stresses the need for continued high priority in such investigations. Furthermore continued high priority should be given to current development of legislative and regulatory actions, until there is a better understanding of the effects of contaminants on the health of the ecosystem including man. The Board emphasizes these points for two reasons: firstly, we feel that the dispersal and the subsequent potential effects of toxic substances in the Great Lakes should remain the highest priority issue for the management of the Great Lakes. Secondly, we are concerned that the recent economic conditions in both U.S. and Canada may result in political pressures to ease concerns, legislation and regulations with regard to the discharge of potential contaminants.

Toxic Substances and 1978 Agreement

The Science Advisory Board has reviewed the Annexes of the 1978 Great Lakes Water Quality Agreement which pertain to the control of chemical contaminants. These Annexes are attached (Appendix A) to this report for ready reference. The opinions and recommendations of the Board as a result of this review were summarized in a letter to the Commission on March 27, 1979, which reads as follows:

"Proposed Plan for Implementing Annexes 10 and 12 of the 1978 Water Quality Agreement"

"Perhaps any discussion of how to deal with chemical contaminants in the Great Lakes should begin by deciding why these are singled out and what makes them different and need special treatment. Having identified the answer to these questions, then solutions may be more obvious."

"One difference that is apparent at the outset is that the chemicals of most concern are those that are most toxic. "Most toxic" for purposes of the Great Lakes must be defined as those for which the exposure--length of time and concentration present--results in the greatest potential for adverse effects. Toxicity is only one characteristic of concern in evaluating the probable exposure: persistence is equally important in assessing hazard. Ozone for example is very toxic but it is much less of a hazard because it persists only for a few seconds or minutes. Others may exert their effect indirectly such as the impact of freons on the ozone layer."

"A second difference about the chemicals of concern is that they constitute a vast number and are chemically and physically very different. Furthermore, the total number, the chemical-physical characteristics, the quantity and the sources are poorly known. Neither is it practical to analyze surveillance samples for all or even most of these chemicals. Furthermore, there certainly are many other by-product chemicals associated with the production and use of chemicals in commerce."

"From these characteristics, it is clear that any plan to effectively control chemicals must:

(1) consider the toxicity, persistence and quantity produced in the Great Lakes Basin Ecosystem;

(2) contain a mechanism for selecting those of most probable hazard;

(3) contain a priority plan for promoting development of needed data that are lacking - from biological effects to control technology;

(4) identify locales of most probable occurrence if surveillance needs are to be made realistic."

"Accepting these characteristics as important, it is clear that (1) the lists currently in Annex 10 must be revised and (2) a working data base is needed to provide candidate chemicals to the Parties for placement on the lists. These lists are much too rigid and difficult to change to be used as working lists, given the massive lack of information."

"Further note that the main characteristics of pollutants identified in Annex 12, are equally important characteristics in Annex 10. As an example, calcium is a persistent substance but was probably not one intended to be considered with special interest under Annex 12. Calcium is at the other extreme from ozone in that it is undestructable but has a very low toxicity and therefore a low hazard. In view of this, the two Annexes should be treated together."

"The Science Advisory Board suggests the following approach towards responding to Annexes 10 and 12:

(1) The Appendices 1 and 2 of Annex 10 should be defined as those chemicals of <u>certain</u> high hazard and <u>suspected</u> high hazard respectively. A task force of the two Boards should be appointed to refine the Appendices based on this definition.

(2) A Science Advisory Board Committee should establish a mechanism to collect, review and synthesize data on chemicals and their interaction in the Great Lakes Basin Ecosystem and recommend to the Water Quality Board placement on list 1 or 2.

(3) The Water Quality Board should establish a mechanism to gather production, transport and discharge data on individual chemicals in the Basin. This step is critical to success of the entire program. Both #2 and #3 would require substantial staff support.

(4) The inventory and data base developed by the Science Advisory Board and the EPA Duluth Laboratory should be used as the working mechanism for processing the massive amount of data that will be generated. Further, the Regional Office in Windsor

should be assigned the responsibility of maintaining and updating the base at the direction of the Science Advisory Board Committee identified in #2 above.

(5) The Commission should be responsible to see that proper enforcement and surveillance is achieved by the Parties."

"A concerted effort should be expended to assure that all other data bases are examined for useful information. Experience to date suggests they may be useful but not complete for International Joint Commission needs. Many are not yet truly operational."

"The above described activity could well become a large part of our water quality objectives activity. Identified data deficiencies will also provide guidance to the Science Advisory Board and the International Joint Commission for needed research to be recommended to governments."

The Science Advisory Board requests the International Joint Commission to obtain from the Parties an immediate commitment to review the Board's recommended procedure for addressing Annexes 10 and 12 of the 1978 Water Quality Agreement. Adoption of a procedure is urgently required due to the vagueness of the Annexes with regard to the mechanism of their implementation and due to the urgency of addressing the toxic substances issue in the Basin.

The Ecosystem Approach and Toxic Substance Control

The development of water quality objectives as required by the 1972 Great Lakes Water Quality Agreement was necessary due to the immediate need to evaluate the potential environmental and human health impact of the many contaminants being detected within the Great Lakes Basin Ecosystem. Remedial measures were implemented in response.

As noted earlier, a committee of the Research Advisory Board worked with a subcommittee of the Water Quality Board to develop specific objectives. The two groups evolved and adopted what they considered to be a scientifically defensible framework for the development and refinement of objectives. Their proposed objectives are predicated on this framework. On the basis of the framework and the groups' activities the Board highlights two major concerns to the Commission:

1) *The groups recognized that the objectives could not take into account the possible effects of multiple contaminants. As a result, they stated "adoption of objectives <u>does</u> <u>not</u> preclude the need for studying the aquatic environment and effects of conditions on related organisms and uses".*

They further stated: "Each objective alone should provide protection from effects of that specific condition. Within each objective a safety factor is used which may be very small for some conditions and unknown for others. It cannot be assumed that when two or more minimum conditions (specific numerical objectives) occur simultaneously that protection of use is assured or that considerable overprotection is not involved. Antagonistic, additive or synergistic effects may occur. Considering the infinite combinations of water quality characteristics, it may never be possible to predict the effects of these combinations even for adult organisms, much less for their life history stages and processes".

"Furthermore, local biota and local natural or ambient water quality characteristics coupled with a particular objective can result in a different response than that assumed by the Committees. In local conditions therefore an objective may be more restrictive than necessary and conversely, regulatory agencies should not assume that meeting the general and specific objectives guarantees protection of uses."

This important concern is frequently forgotten in assessment of the status of the Great Lakes System.

2) *The approach of the groups was to identify possible contaminants of concern and to evaluate the potential effects of the contaminants, individually, on the "most sensitive use" - i.e. aquatic life, their consumers or human health.* There was concern that many contaminants were not being evaluated because they had not been identified.

These two concerns have, in part, implied the need for an alternative approach for the derivation of objectives. One alternative approach is inherent within an Ecosystem Approach.

In July 1978, the Science Advisory Board and the Water Quality Board reestablished the groups responsible for objectives. A Science Advisory Board committee (Aquatic Ecosystem Objectives Committee) has been assigned to develop "aquatic ecosystem objectives" which would include consideration of "water quality objectives." A Water Quality Board subcommittee (Objectives Assessment Subcommittee) will assess the technical and socio-economic implications of implementing the recommended objectives. One concern already expressed by the Science Advisory Board's committee is that the specific goals and desired uses of the Great Lakes have not been adequately delineated.

The Aquatic Ecosystem Objectives Committee decided to undertake a two prong approach. Firstly, because of the continual identification of new contaminants of concern within the Great Lakes, the Committee will assess the potential impact of these contaminants within the Great Lakes Ecosystem. Secondly, the Committee will undertake a feasibility study of developing holistic ecosystem objectives. The approach would, for example, attempt to develop a means of determining effects of various stresses on the biotic community through observation of the changes in community structure and behavior. One objective could be the maintenance of a specific community structure. This approach would not only forecast possible effects of stresses from chemical inputs (i.e. toxic substances, nutrients) to the Great Lakes, but also cultural and demographic* stresses. The approach of the Committee is to:

1. describe the aquatic subsystems of the Great Lakes Basin Ecosystem in their near pristine states according to hydrographic characteristics, biotic communities and cultural influences;

2. define reasonable aquatic ecosystem objectives for the lakes given current cultural immutables;

3. identify major stressors on each subsystem that would inhibit achievement of the objective in 2, above;

4. detect the principal causes of the combined stresses;

The Committee has solicited expert help to determine various Great Lakes ecosystem descriptors which should be monitored to assess the status of the Great Lakes ecosystem. As well as the identity of such descriptors, the Committee will be concerned about adequate quantification and the existence of historical data.

The aquatic ecosystem approach and the methodologies employed in the establishment of water quality objectives are closely interdependent. The advantages of undertaking an aquatic ecosystem approach are as follows:

1. The aquatic ecosystem approach will expand the scope of concern by considering community and subsystem levels. As an example, phosphorus is used currently as a descriptor of associated phytoplankton levels in the environment. However, it is also characteristic of other biotic communities most likely to inhabit the particular environment - such as fish community structures.

2. With regard to toxic substances, continual observation of selected ecosystem descriptors will: enable a rapid detection of synergistic and additive effects; enable an assessment of the adequacy of existing objectives; and, identify new chemical contaminants of concern.

3. Surveillance requirements would be better identified.

4. The approach will expand beyond the realm of "chemicals and the Great Lakes" to include the possible effects of cultural, socio-economic and technological changes. Thus human activities

*The Board's 1978 Special Report: "The Ecosystem Approach" uses the term "demophoric" to "express the combined biological and technological metabolism of MAN in consumption of resources and production of wastes."

will be considered in terms of their interaction with other parts of nature rather than viewing man as separate from nature. For example the effects of shoreline development, energy use patterns and extended navigation seasons would be more easily evaluated.

The Board wishes to emphasize to the Commission that outside of the Great Lakes Basin, broader "ecosystem" approaches as advocated by the Board's Committee on Aquatic Ecosystem Objectives have been undertaken to various degrees by several governments and international organizations. The concept is neither new nor is it without scientific foundation.

In 1964 the International Biological Program (IBP) initiated the development of a world-wide plan of research concerned with the "biological basis for production and human welfare." In 1971, the Man and Biosphere Program (MAB), which was sponsored by UNESCO, was formed with the objective "to develop the basis within the natural and social sciences for the rational use and conservation of resources of the biosphere and for the improvement of the global relationship between man and the environment." The scientific approach of the MAB Programme can be categorized as including major components on the analysis of ecological systems, reciprocal studies of man-environment impacts, integration of information over various spatial levels, and inclusion of modelling techniques to allow quantitative predictions.

Briefly, the programme is intended to:

(i) identify and assess changes in ecological systems;
(ii) examine the structure, functioning, and dynamics of ecosystems;
(iii) study the interrelations between ecosystems and socio-economic processes;
(iv) develop means for measuring environmental changes;
(v) increase global coherence of environmental research;
(vi) promote simulation and modelling as tools for environmental management; and,
(vii) promote environmental education.

The objectives are to be interpreted in the context of man, the biosphere, and the reciprocal interactions of one upon the other.

In addition, integrated biological and chemical assessments are particularly prevalent in many European countries and utilized within an ecosystem concept.

The activities described above show the vast expansion of the Board's scope of concern in addressing the "toxic substance" issue. The activities of the Aquatic Ecosystem Objectives Committee, the Water Quality Board's Objective Assessment Subcommittee, the Committee on the Assessment of Health Effects of Great Lakes Water Quality and the SAB pilot effort on predictive capabilities are certainly components of an ecosystem approach. Other components will have to be addressed in the near future - such as the interrelationships between ecosystems and socio-economic processes.

C. Socio—Economic Futures

Workshop on Anticipatory Planning

As mentioned in the introduction, the concerns of the 1972 and 1978 Great Lakes Water Quality Agreements have addressed chemical stresses on the Great Lakes ecosystem. However, additional stresses are possible from other human activities. For example, changes in cultural patterns affect land and biological resources in addition to water resources.

In March 1979, the Board's Expert Committee on Societal Aspects sponsored a workshop which attempted to identify problems which may emerge within the Great Lakes Basin in the short and long term as a result of future trends in: urban growth; land use (natural resources); local and regional planning; transportation; energy; investment and finance; Great Lakes region comparison to other areas of Canada and the United States; and, technological and social change. Experts in each of these areas were invited to document and discuss, for example, predicted energy requirements in the Great Lakes areas within the next 5-10 years and possible technologies which will be used to meet these requirements. Urban planners discussed predicted population trends in the Great Lakes Basin and possible impact of urban growth on neighboring agricultural lands. Investment and finance groups considered which social and economic activities, in the next 5 to 10 years, may impact development within the Great Lakes Basin.

The workshop deliberations, when synthesized later this year, may provide greater insights relevant to the present and future effects of man in the Great Lakes. This information will enable governments to undertake long range programs to address emerging problems. Furthermore, the workshop identified some of the major Great Lakes information and planning entities in the private and public sectors which will have a major bearing on the future characteristics of the water and land resources of the Great Lakes Basin.

Environmental Mapping

Environmental mapping is one tool which may aid future management efforts in the Great Lakes Basin. In its 1978 report to the Commission, the Board noted that we had formed a task force to evaluate the potential for environmental mapping of the Great Lakes. The task force completed its deliberations and its final report is appended to this report (Appendix B).

Environmental mapping as defined in the task force report, is a visual display of data where information is organized in various forms such as maps, figures, tables and text. The task force indicated that such visual display of data can contribute to the goals and objectives of the 1978 Great Lakes Water Quality Agreement, because:

1. It is a means by which regional perspectives are provided as a context for local decision-making.

2. It is a means by which data and information derived from diverse sources and disciplines can be synthesized into a suitable format.

3. It provides an opportunity for the historical perspective to highlight areas of special concern requiring attention or to demonstrate achievements in ecosystem improvement.

4. It provides a mechanism for the identification of ecosystem problems, gaps in available data, or weaknesses in existing information.

5. It serves to coordinate and reorganize thinking about the problems of a complex ecosystem.

Within the context of the Agreement and its relationship to public information, resource management, and planning, the task force stated that suitable goals for an environmental mapping activity are to address issues of concern and to provide information:

1. to improve understanding of the Great Lakes ecosystem and the dynamic interrelationships involved among the biological, chemical, physical, and societal components of the environment; and,

2. to assist in Great Lakes planning and management decisions that affect the Great Lakes ecosystem.

With these goals in mind, environmental mapping objectives are:

1. to synthesize and display knowledge of the Great Lakes ecosystem;

2. to provide perspective on societal activities stressing ecosystem quality;

3. to aid decision makers and an informed public to reach complementary decisions and to implement programs to achieve mutually agreeable management objectives under the Water Quality Agreement;

4. to deal with issues affecting the Great Lakes ecosystem including past to present trends and potential future problems; and

5. to improve understanding of the Great Lakes ecosystem in order to develop a broader base of support for the actions required to achieve the goals.

Due to differing perceptions of environmental mapping and differing agency missions and policies, consensus was not reached on the single most appropriate and useful topic for environmental mapping. Therefore, three candidates were offered: toxic contaminants, eutrophication or rehabilitation.

Following a review of the task force report and the task force's recommendations, the Science Advisory Board accepted the report, and (1) agreed in principle that environmental mapping is a powerful tool of great potential use to the IJC and all those participating within the Water Quality Agreement; and (2) acknowledged strong differences of opinion on several aspects of environmental mapping. The Science Advisory Board itself is not unanimous on the approach and the topic for an initial mapping effort. This again is due to differing perceptions of environmental mapping. In reality an unanimous consensus on environmental mapping in the Great Lakes does not seem possible.

The Commission in its 1977 report to Governments, upon recommendation by the Research Advisory Board, endorsed "the concept of environmental mapping for the Great Lakes," and encouraged "the Parties to the Agreement to initiate an experimental international project to map a sub-area of the Great Lakes in order to determine the costs, benefits, potentials and problems of such a mapping program."

The Canadian government response to the Commission's report acknowledged "the Commission's endorsement of the concept of environmental mapping" and stated Canada "will consider the recommendations for initiation of an experimental international project to map a sub-area of the Great Lakes."

The Board is aware that several Great Lakes Basin agencies are interested in environmental mapping and some do have funding for such efforts. The majority of the Board members are convinced that an environmental mapping activity must be initiated within the Basin to illustrate the potential uses of mapping. Therefore the SAB recommends that the IJC:

Request the Parties to identify United States and Canadian institutions with interests in environmental mapping and to identify agencies with resources which can be allocated to an initial effort. Contingent upon adequate agency support the Commission establish a task force to coordinate and assure implementation. Topics recommended for consideration are: toxic contaminants, eutrophication and rehabilitation.

D. Great Lakes Eutrophication

In the Board's 1978 report, a number of committee and task force activities were described which addressed the eutrophication issue within the Great Lakes. Also, background was provided on the establishment of a Science Advisory Board Task Force on Phosphorus Management Strategies which would:

1. "Review and evaluate the adequacy of existing data, knowledge and technology pertinent to the development of alternative phosphorus management strategies. Items of concern to include: costs associated with nonpoint and point source control; costs associated with reduction of phosphorus content in detergents; phosphorus loadings characterization, etc.

2. Evaluate the potential ecological, economic and health related impacts of alternative management strategies, giving the strengths and weaknesses of each for consideration by policy-makers.

3. Test the appropriateness of such strategies against alternative environmental futures (adverse economics, energy constraints, etc.).

4. Identify specific subject areas where additional information is needed."

Furthermore the 1978 Annual Report stated that:

"The approved task force besides serving a timely and extremely important function under the Great Lakes Water Quality Agreement, also will launch the anticipated prime future functions of the Research Advisory Board which are to focus on the implications of long-term trends of human activities in the Great Lakes Basin, and subsequently focus on preventative measures which can be taken "here and now" to assure ecosystem quality in the Great Lakes. The mechanics of this anticipated function would be through the use of staged scenarios to illustrate available management options. The scenarios would, for example:

- o foresee necessary institutional arrangements;
- o illustrate general patterns of events which may result;
- o be a basis for general strategy development for governments for future legislation, programs, etc.; and
- o define fall-back positions which may result from emergencies.

The Task Force on Phosphorus Management Strategies will be considered as a first phase of a "nutrient scenario" for the Great Lakes Basin Ecosystem."

During 1978-79, the Phosphorus Management Strategies Task Force actively pursued its terms of reference. Two other task forces and one of the Board's Expert Committees are addressing components of the phosphorus-eutrophication issue.

Task Force on Phosphorus Management Strategies

Among the activities undertaken by the task force during 1978-79 were:

- evaluation of models used to derive the proposed target loads to the Great Lakes presented in the 1978 Great Lakes Water Quality Agreement;

- assessment of "present" (1976) phosphorus load estimates of: The Pollution from Land Use Activities Reference Group; Task Group III (a bilateral working group consisting of United States and Canadian scientists given the responsibility of deriving phosphorus loading objectives for the 1978 Great Lakes Water Quality Agreement); and, the Water Quality Board, all of whom had different estimates (this activity was undertaken because the 1976 phosphorus loads were used as a reference value to derive the loading objectives);

- formulation and evaluation of phosphorus control technologies and their associated costs; and,

- evaluation of cost/effectiveness of phosphorus control measures from a socio-economic perspective (as contrasted with the traditional limnological and/or engineering evaluation);

The task force revised and expanded its terms of reference to give consideration to concerns raised by the Water Quality Board. Several items were added to the terms of reference including: (a) review of the availability and practicality of phosphorus control technology and associated costs of control of point and nonpoint phosphorus sources; (b) consideration of the biological availability of phosphorus in formulation of alternative management strategies. Following deliberations with the Water Quality Board, the Science Advisory Board and the task force agreed to add four new members designated by the Water Quality Board. In effect, the task force is now being considered as a joint effort of both Boards.

The task force, through the International Joint Commission, jointly sponsored a three-day conference with Cornell University entitled "Phosphorus Management Strategies for the Great Lakes." The purpose of this conference was to provide a "state of the art" summary concerning alternative strategies, and related components, that should be considered for control of phosphorus in the Great Lakes Basin. The materials presented at this conference, which had more than 200 attendees, included: (a) nonpoint phosphorus sources in the Great Lakes Basin; (b) a summary and discussion concerning the phosphorus mathematical models used to formulate the 1978 Great Lakes Water Quality Agreement loading objectives; (c) a review of current phosphorus control objectives and the rationale underlying the proposed phosphorus target loads; (d) identification of current phosphorus management strategies and discussion of how well they are working; (e) discussion of other strategies that should be considered; and (f) discussion of technical, economic and institutional aspects of possible control strategies.

The final report of the task force is to be completed by January 1980. It is anticipated the report will contain five major chapters on:

(i) evaluation of phosphorus inputs to the Great Lakes (point and nonpoint sources and biological availability);

(ii) impact of phosphorus loads on phosphorus and algae levels in the Great Lakes (evaluation of models; verification of predictive capability of models; past phosphorus controls and responses of lakes to these controls).

(iii) phosphorus target loads (rationale and development);

(iv) costs and technologies of phosphorus controls (point and nonpoint control options; types of treatment - chemical, biological, land disposal, etc; detergent phosphate substitutes; and sludge generation);

(v) strategies and recommendations (optional management strategies to achieve objectives by use of various cost/effectiveness and socio-economic evaluations of phosphorus control).

All identified areas of concern are receiving thorough review by the task force. For example, in the review of available technological solutions, the task force will consider: physical processes (membrane processes); biological processes (luxury uptake, phostrip, Bardenpho); chemical processes (lime, metal salts, etc.); biological plant operations (fixed film and activated sludge processes, aerated lagoons and waste stabilization ponds); and effluent application to land.

Expert Committee on Engineering and Technological Aspects

This committee played a prime role in the initiation of the Task Force on Phosphorus Management Strategies. It has subsequently maintained an active role in the review of various topics of interest to the task force particularly: (i) biological availability of phosphorus; (ii) technological and economic assessment of two existing wastewater treatment systems; (iii) sludge disposal; and (iv) reliability of municipal wastewater treatment plants for phosphorus removal. Also the Expert Committee visited with federal research granting agencies to discuss current and future related research funding levels.

(i) In December 1978, a subcommittee of the Expert Committee met with several experts to discuss: available techniques to determine short and long-term availability of phosphorus; existing sources of phosphorus inputs to the Great Lakes and their relative inputs of available phosphorus; and, high priority information and research needs which require immediate action. It is expected that a report on this review will be available in late 1979.

(ii) The Expert Committee obtained operating performance data from two "advanced" wastewater treatment plants: the Tahoe-Truckee Sanitation Agency Advanced Wastewater Treatment Plant and the South Tahoe Water Reclamation System. The former has stringent discharge standards with the maximum average constituent limits: COD, 15 mg/L; suspended solids, 2 mg/L; total nitrogen, 2 mg/L; and total phosphorus, 0.15 mg/L.

The intent of the Committee is to assess phosphorus and nitrogen removal efforts at the plants and the long term reliability of the efforts. Sludge quantities, handling and disposal, as well as economics of operation and energy requirements are to be especially considered.

In spring of 1979, one year of operating data from the Tahoe-Truckee plant will be available, and the Committee will carefully evaluate the operations to enable more meaningful comparisons with other technologies such as land disposal.

(iii) The Committee by direct contact with Canadian and U.S. federal environmental research funding agencies reviewed the adequacy of funds allocated for sludge disposal research. For example, in Washington, D.C., several programs were described to the committee including: The National Science Foundation "proof-of-concept" sludge management program ($3 million, FY/74-FY/78); EPA Municipal Wastewater Research Program - sludge management ($3.8 million FY 78/79); and the Greater Chicago Metropolitan Sanitary District sludge disposal research program ($2 million per year).

Canadian efforts were primarily funded by the Canada-Ontario Agreement on Great Lakes Water Quality which had a provision for a research program directed towards reducing the cost of waste treatment programs as well as ensuring that the latest technological advances are incorporated into such programs. Funding of this activity has been shared equally by the Federal and Provincial governments for a total of $7.0 million over a period of seven years. Seven broad areas of research activities were pursued, one of which dealt with land disposal of sludge. After the Canada-Ontario Agreement expired, Canadian sludge research programs have been funded primary by Ontario Provincial Lottery Funds and by Environment Canada.

Following the review, the Expert Committee on Engineering and Technological Aspects felt that the funding for sludge research should at least remain at the present level. It was noted most of the efforts were directed towards sludges from municipal waste treatment plants. The committee noted few research efforts on resource recovery from sludges.

(iv) A significant aspect in phosphorus control within the Great Lakes Basin, is the issue of operation and maintenance of municipal wastewater treatment plants. Recently the Remedial Programs Subcommittee reported to the Water Quality Board an increase in the number of discharges in both countries which were in compliance with their respective pollution control requirements. The level increased from 54% in 1977 to 71% in 1978. The Subcommittee stated "a higher rate of compliance basinwide would be expected if dischargers followed optimum operation and maintenance procedures to ensure that performance approached the design efficiency of the facilities and if programs were in effect to continually upgrade the skills of the operators."

Key regulatory agencies in Canada and United States held a binational workshop in 1978 to address the operational efficiency of municipal wastewater treatment facilities and to consider specific management and technical alternatives which could lead to their improved performance.

The attendees of the workshop identified major areas of deficiency which included:

- Public awareness and support of proper operations and maintenance.

- O&M budget levels.

- Number and technical capability of operators, equipment service representatives and regulatory review authorities.

- Maintenance plans.

- Regulations relating to permit requirements and equipment selection procedures.

- Design considerations related to operational and maintenance reliability.

- Accountability for long-term operability.

The O&M "problem" includes a spectrum of sub-issues which vary in severity and applicability among wastewater treatment facilities. This complexity was recognized and addressed in the solutions proposed by the workshop participants. Many alternatives were discussed. The preferred solutions identified at the workshop would:

- Federally fund, on a one-time basis, operation and maintenance improvement grants. The purpose of these grants would be to independently establish a comprehensive correction program including preparation of an O&M manual, cost-accounting procedures, preventative maintenance plans, staffing recommendations, and specific training requirements emphasizing on-site training.

- Require mandatory operator certification.

- Incorporate independent review of facility designs in terms of operational and maintenance and reliability considerations.

- Incorporate in future wage negotiations incentive pay schedules for operators based on permit compliance monitoring.

- Publicize locally the cost-effectiveness of O&M expenditures in improving water quality.

- Provide greater emphasis in equipment specification and procurement processes to insure, even at higher initial capital cost, more reliable equipment.

- Redirect research emphasis from new process development to operations and maintenance considerations of existing technology.

It is obvious that many segments of our society have a contribution to make with regard to improved operation and maintenance of wastewater treatment facilities. EPA has for example: (1) accelerated its enforcement activities against major municipal treatment facilities which are not in compliance with discharge permits. (2) changed the emphasis of its Operations and Maintenance Research Program at the Municipal Environmental Research Laboratory to address design and operational deficiencies of existing technology related to O&M problems, and (3) is seriously considering making independent review of facility designs for operational, maintenance and reliability considerations mandatory for construction and grant funding. These latter two actions are directly supportive of preferred solutions identified by the workshop attendees.

In the Province of Ontario, O&M does not appear to be a major research concern. High priority is currently given to information exchange and development of uniform sampling and monitoring programs to assure appropriate performance evaluations. It was further noted that the Ontario Ministry of the Environment which has been directly responsible for the O&M of many Ontario municipal wastewater treatment plants, is slowly transferring this responsibility back to municipalities. The possible effects of this transfer is not known, particularly in the case of municipalities with "tight" resources.

(v) As noted previously, the Expert Committee on Engineering and Technological Aspects discussed research programs and funding levels with representatives of U.S. EPA, National Science Foundation, Canada Department of Environment and the Ontario Ministry of the Environment. The topics of discussion were Great Lakes water quality issues as identified in the PLUARG final report "Environmental Management Strategies for the Great Lakes System" and the Water Quality Board's 1977 report to the Commission. Many of the issues were pertinent to the topic of phosphorus control and a few are mentioned above. In general, research activities related to the following topics were discussed: O&M of municipal wastewater treatment plants; disposal of municipal sludges; disinfection; toxic surveys of treated wastewaters; control of urban runoff; control of ammonia; pretreatment of industrial wastes prior to discharge into municipal systems; management of hazardous waste disposal; disposal of industrial sludges; effluent limitations and effects on water quality; modelling; mixing zones; bioavailability; control of international air pollution; and, cooling water intake design.

Program descriptions were obtained for each of the identified issues. The committee will, in the near future, identify areas which might not be adequately funded and subsequently discuss these areas of concern with the Science Advisory Board.

Science Advisory Board Views on Land Application of Municipal Wastewaters

The Board is aware that land application of municipal wastewater, in particular the rapid infiltration and slow-rate crop-irrigated alternatives may have high phosphorus removal capabilities. Evaluation of land treatment and facilities planning has been mandatory under PL-92-500 since July 1, 1974. The EPA Construction Grants Regulations as published in the Federal Register, Volume 39, Number 29, February 11, 1974, provided for coverage of land application techniques in facility planning. PL-95-217 re-emphasizes the use of innovative alternative systems including land treatment with many tangible incentives including (1) the "115%" cost preference, (2) 85% Federal Grants with the specific set asides, (3) the eligibility of land for storage as well as treatment functions, and (4) 100% grants for modification or replacement if a project fails to meet design criteria.

Use of the technique will require assessment of soil and groundwater characteristics, climate, agricultural opportunities as well as present and anticipated land use patterns.

Further review is underway within the IJC framework. The Task Force on Phosphorus Management Strategies is evaluating various techniques for phosphorus removal including land application. The Water Quality Board is also assessing the technique. If additional information is required, the SAB will direct its Expert Committee on Engineering and Technological Aspects to provide its expertise and assessment.

Task Force on the Health Effects of Non-NTA Detergent Builders

Efforts are well underway to evaluate the potential health effects of the following detergent builders: citrates; carboxymethyl-oxysuccinate (CMOS); Builder "M"; phosphates; carbonates; silicates; zeolites; and borax. The information under consideration includes assessment of: potential environmental levels; acute toxicity (skin, eye, LD_{50}, sensitization); subchronic toxicity (28-30 day general toxicity with later study of metabolism and pharmokinetics); chronic toxicity (6 months - 2 years) carcinogenicity; mutagenicity; and teratogenicity.

The results of the evaluation will be published in a report of the Science Advisory Board by 1980. This report will complement an earlier report of the Board on the health implications of the use of NTA as a detergent builder.

Task Force on the Ecological Effects of Non-Phosphate Detergent Builders

Recently this task force published a report which assessed the ecological effects which may be associated with the widespread use of NTA as a detergent builder. This report and the report of the task force to evaluate the health implications of NTA are currently under review by the U.S. EPA Office of Toxic Substances, which was requested in 1978 to provide an opinion on the use of NTA as a detergent builder.

The task force is evaluating potential environmental effects from the use of other detergent builders including: citrates, carboxymethyloxysuccinate (CMOS), carboxymethyltartronate (Builder "M"), carbonates, silicates and aluminosilicates (zeolites). A final report by the task force is expected in 1979.

By means of the above review, it can be seen that significant resources are being placed by the Science Advisory Board, its committees and task forces to help address the issue of Great Lakes eutrophication. The Board's current efforts on this issue will be integrated within the findings of the Task Force on Phosphorus Management Strategies.

5 CONCLUSIONS

A broader approach to address Great Lakes issues has been undertaken by the Board for identification of problems and information needs within the Great Lakes Basin. By taking this approach, the Board has thus far shown that:

- acid precipitation, although not directly affecting the pH of the Great Lakes open waters, will affect the Great Lakes Basin Ecosystem by various pathways.
- the Great Lakes Basin is being impacted by air emissions from sources outside the Basin, and emissions within the Basin are being exported to ecosystems outside of the Basin. As a result, legislative and socio-economic concerns will have to be broadened.
- the effects of toxic substances and long range transport of air emissions are of global concern, and the issues are being addressed by several multi-national and multi-agency groups throughout the world. Liaison of the Great Lakes efforts with the efforts of such groups needs to be strengthened.
- the development of common objectives for the Great Lakes system, requires that the Parties articulate specific goals and desired uses of the Great Lakes so that more direct efforts can be formulated to reach these expectations.
- it is necessary to expand the Great Lakes concerns from "the effects of chemicals in the Great Lakes" to the effects of man's many activities which include changes in land-use patterns, shoreline development and cultural practices.

6 BOARD OPERATIONS

Under the Great Lakes Water Quality Agreement of 1978, the Science Advisory Board is an advisor to the International Joint Commission and the

Commission's Great Lakes Water Quality Board. The Science Advisory Board is responsible for developing recommendations on research and developing statements on the state of scientific knowledge pertinent to the identification, evaluation, and resolution of current and anticipated water quality problems on Great Lakes.

To meet its responsibility as the scientific advisor to the Commission and the Water Quality Board on matters relating to Great Lakes water quality, the Board draws upon the knowledge of its members who are experts in scientific, engineering and societal fields from governmental, industrial, university, and private sectors. Further, the Board appoints committees and task forces, from time to time, and holds workshops and conferences to assist in developing information and to provide scientific advice.

The committees have contributed greatly toward the Board's perception of issues which pertain to the Great Lakes ecosystem and the task forces have developed essential information and reports over this past year.

COMMITTEES

The Board has three Expert Committees to provide continuing independent advice and synthesis of scientific opinion on new and continuing Great Lakes programs. These three committees also identify oversights, weaknesses, and opportunities in Great Lakes research activities in Canada and the United States. Two other committees deal with more specific issues. The following is a summary of the scope and activities of each of the committees since July, 1978.

Expert Committee on Engineering and Technological Aspects of Great Lakes Water Quality

This committee's scope of activities encompass in part the technological procedures and treatment of the effects of man's activities undertaken either prior to or after entry into receiving waters. The committee includes members with expertise on industrial waste treatment, municipal waste treatment, agriculture, land use, and hazardous materials.

The recommendation by the committee that a phosphorus management strategy task force be formed was accepted and that task force has been formed.

The committee reviewed the previous Water Quality Board and PLUARG reports to identify existing Great Lakes engineering and technological issues. The identified issues were: operation and maintenance of municipal wastewater treatment plants; disposal of municipal sludges; disinfection; toxic surveys of treated wastewaters; control of urban runoff; pre-treatment of industrial wastes prior to discharge into municipal systems; management of hazardous waste disposal; disposal of industrial sludges; effluent limitations and effects on water quality; modelling; mixing zones; bioavailability; control of international air pollution; and, cooling water intake design.

The committee has recently met with key officials of the U.S. Environmental Protection Agency, U.S. National Science Foundation, Ontario

Ministry of the Environment, and Environment Canada to determine the extent of research activities addressing the identified water quality issues.

The committee formed a subcommittee which met with several experts to discuss the current knowledge on the measurement and assessment techniques for determining biologically available forms of phosphorus and sources, and their relative input to lakes.

The following additional topics are being addressed: operation and maintenance of municipal wastewater treatment plants; modelling; disinfection; mixing zones; and, evaluation of costs, energy requirements, sludge production and reliability of advanced wastewater treatment plants.

Expert Committee on Ecological and Geochemical Aspects of Great Lakes Water Quality

This committee's area of responsibility includes those issues relating to ecological and geochemical effects of man's activities.

The major activity of this committee during the past year has been to research the effects of acid rain and to acquaint the Board with information on the subject. The Board, in its discussion on acid rain within this report, has incorporated many of the findings supplied by the committee.

Expert Committee on Societal Aspects of Great Lakes Water Quality

The jurisdictional, political, institutional, legal, educational and other non-physical measures influencing the effects of man's activities on receiving waters are considered by this committee. The committee includes expertise representative of economics, energy issues, planning, citizen/public interest, political science, human behavior, legal aspects, and regulatory activities.

The Expert Committee recommended that the Board sponsor a workshop on anticipatory planning. The Board and Commission approved in principle the workshop which was held in early March of this year. Its goals were to:

- discern key Great Lakes planning entities in the private and public sectors with whom the Commission should be in contact;
- develop a mechanism to interface these entities with the International Joint Commission; and
- identify and define major Great Lakes problems not being adequately addressed and likely problems emerging within the next five to ten years.

Proceedings of the workshop will be published shortly.

The committee is currently engaging in an analysis of the Water Quality Agreement of 1978. Presently the efforts are directed toward those portions of the Agreement which have specific relationship to and impact on the activities that are to be instituted from recommendations set forth by the Pollution from Land Use Reference Group Report to the International Joint Commission.

Aquatic Ecosystem Objectives Committee

To better effect the deliberative process in developing objectives for the Great Lakes, the Water Quality Board's Water Quality Objectives Subcommittee and the Science Advisory Board's Scientific Basis for Water Quality Criteria Task Force were disbanded and replaced by two new groups, the Aquatic Ecosystem Objectives Committee (AEOC) and the Objectives Assessment Subcommite (OAS). The Aquatic Ecosystem Objectives Committee is charged to:

- Develop aquatic ecosystem objectives. Where feasible, these should be in the form of use-effect curves, for various uses, and always including the most sensitive use.

- Regularly review objectives and recommend their amendment or the introduction of new objectives based upon all available criteria.

- Establish task forces to develop position papers on which to base the development of new or altered objectives.

- Set general guidelines under which the objectives will be developed and define some minimum levels of scientific information at which an objective can be defined.

- Assist the Objective Assessment Subcommittee (OAS) of the WQB in its development of supporting documents for the economic, social, and regulatory assessment of proposed objectives.

- AEOC and the OAS will jointly develop an approach for the selection and ordering of parameters to be addressed.

- Identify gaps in the knowledge needed to develop objectives and recommend the research required to fill the gaps.

Since its formation, the committee has undertaken the following tasks:

- o development of methodology to define aquatic ecosystem objectives;
- o re-evaluation of the objectives for mercury and lead within an ecosystem approach;
- o assembly of current research information on dioxin and pentachlorophenol for consideration of possible objectives.

Also AEOC is reviewing an oxygen objective that was recommended to the Board by a special review committee as an alternative to an objective for oxygen developed previously.

Joint Science Advisory Board/Water Quality Board Committee on the Assessment of Human Health Effects of Great Lakes Water Quality

This joint committee of the two Boards was formed in early 1978. Its activities include:

- assessment of health risks posed by contaminants in the Great Lakes;

- review of action levels and guidelines for selected substances;
- interpretation and consultation on health matters; and
- maintaining an awareness of current advances in knowledge regarding health effects of water constituents.

Two of the major activities undertaken by this committee in the past year include the evaluation of lead in the environment and the evaluation of the 400 organic compounds identified in the 1978 report entitled "Status Report on Organic and Heavy Metal Contaminants in the Lakes Erie, Michigan, Huron and Superior Basins". A summary of findings is included in this year's Water Quality Board Report as Appendix G.

TASK FORCES

The Board establishes task forces to deal with specific issues which require intensive interdisciplinary investigations. Such task forces gather and examine information on the specific issues and recommend a course of action, a policy, or an investigative direction necessary in order to reach a solution. The task forces may be established as a result of discussions within the Science Advisory Board, recommendations of the Expert Committees, referrals from the IJC or its groups, as well as referrals from the scientific community or citizen groups. The task forces are disbanded upon acceptance of final reports by the Board.

Ecological Effects of Non-Phosphorus Detergent Builders

This task force was formed in 1976 to provide information to the Board on potential ecological effects of phosphorus substitutes in detergents. Task force members were selected for their respective expertise in the fields of biochemistry, waste treatment, environmental modelling, aquatic toxicology, water chemistry and metal transport, and eutrophication. Initial activities of the task force were directed towards an ecological assessment of NTA. A summary of its findings was reported to the Board in May 1977 and the final report was published this year. The report is entitled: "Ecological Effects of Non-Phosphate Detergent Builders: Final Report on NTA".

The task force is continuing with its assessment of other builders which are currently used or proposed for use.

Health Effects of Non-NTA Detergent Builders

The task force was formed in 1977 to evaluate the potential health effects of detergent builders other than NTA. The task force has since studied citrates and carboxymethyl-oxysuccinate (CMOS), polyphosphates, carbonates, soluble silicates, Builder "M" and carboxymethyltartronate, and is now concluding its investigations on zeolites. The report on these detergent builders is expected to be completed in the fall of 1979.

Phosphorus Management Strategies

Upon the recommendation of the Board's Expert Committee on Engineering and Technological Aspects, a task force on phosphorus management strategies was formed.

The task force has been charged with the responsibility to:

- Review and evaluate the adequacy of existing data, factors affecting phosphorus loads, analysis and technologies pertinent to the development of alternative phosphorus management strategies. Items of concern to include: the assumptions and rationale underlying the phosphorus loads recommended in the 1978 Water Quality Agreement between Canada and the United States on Great Lakes Water Quality, dated November 22, 1978; the availability and practicability of technology and the costs for control of point and nonpoint sources; the reduction of phosphorus content in detergents and associated costs; consideration of the biological availability of phosphorus in the assessment of alternative phosphorus management strategies; and the applicability of systems approaches for determining control strategies.

- Evaluate and test alternative phosphorus management strategies specifically as they impact on: (a) ecology; (b) waste treatment; (c) sludge disposal; (d) energy considerations; and (e) economics.

- Incorporate, as time allows, the findings of the associated task forces and committees on health effects, environmental impacts, societal aspects, and nutrient objectives.

- Identify specific subject areas where additional information is needed.

A final report from the task force is expected by January 1980.

<u>Environmental Mapping</u>

In 1978, the Board formed a task force on environmental mapping to evaluate the potential for environmental mapping of the Great Lakes. The task force completed its study in May 1979 and its report is contained in Appendix B of this report.

<u>Dissolved Oxygen Objective Review Committee</u>

In June 1978, a special committee was established to review the dissolved oxygen objective, proposed previously by the joint Water Quality Board and the Research Advisory Board Committees which had responsibilities for developing water quality objectives. The Dissolved Oxygen Objective Review Committee consisted of four members who were charged to review the proposed objective and to consider the application of new published and unpublished data. In January 1979, the Review Committee reported its findings to the Science Advisory Board.

APPENDIX A

The task force has been charged with the responsibility to:

- Review and evaluate the adequacy of existing data, factors affecting phosphorus loads, analysis and technologies pertinent to the development of alternative phosphorus management strategies. Items of concern to include: the assumptions and rationale underlying the phosphorus loads recommended in the 1978 Water Quality Agreement between Canada and the United States on Great Lakes Water Quality, dated November 22, 1978; the availability and practicability of technology and the costs for control of point and nonpoint sources; the reduction of phosphorus content in detergents and associated costs; consideration of the biological availability of phosphorus in the assessment of alternative phosphorus management strategies; and the applicability of systems analysis for determining control strategies.

- Evaluate and test alternative phosphorus management strategies specifically as they impact on: (a) ecology; (b) waste treatment; (c) sludge disposal; (d) energy considerations; and (e) economics.

- Incorporate, as time allows, the findings of the associated task forces and committees on health effects, environmental impacts, societal aspects, and nutrient objectives.

- Identify specific subject areas where additional information is needed.

A final report from the task force is expected by January 1980.

Environmental Mapping

In 1978, the Board formed a task force on environmental mapping to evaluate the potential for environmental mapping of the Great Lakes. The task force completed its study in May 1979 and its report is contained in Appendix B of this report.

Dissolved Oxygen Objective Review Committee

In June 1978, a special committee was established to review the dissolved oxygen objective, proposed previously by the Joint Water Quality Board and the Research Advisory Board Committees which had responsibilities for developing water quality objectives. The Dissolved Oxygen Objective Review Committee consisted of four members who were charged to review the proposed objective and to consider the application of new published and unpublished data. In January 1979, the Review Committee reported its findings to the Science Advisory Board.

ANNEX 10

HAZARDOUS POLLUTING SUBSTANCES

1. The Parties shall:

(a) Maintain a list, to be known as Appendix 1 of this Annex (hereinafter referred to as Appendix 1), of substances known to have toxic effects on aquatic and animal life and a risk of being discharged to the Great Lakes System;

(b) Maintain a list, to be known as Appendix 2 of this Annex (hereinafter referred to as Appendix 2), of substances potentially having such effects and such a risk of discharge, and to give priority to the examination of these substances for possible transfer to Appendix 1;

(c) Ensure that these lists are continually revised in the light of growing scientific knowledge; and

(d) Develop and implement programs and measures to minimize or eliminate the risk of release of hazardous polluting substances to the Great Lakes System.

2. Hazardous polluting substances to be listed in Appendix 1 shall be determined in accordance with the following procedures:

(a) Selection of all hazardous substances for listing in Appendix 1 shall be based upon documented toxicological and discharge potential data which have been evaluated by the Parties and deemed to be mutually acceptable.

(b) Revisions to Appendix 1 may be made by mutual consent of the Parties and shall be treated as amendments to this Annex for the purposes of Article XIII of this Agreement.

(c) Using the agreed selection criteria, either Party may recommend at any time a substance to be added to the list in Appendix 1. Such substance need not previously have been listed in Appendix 2. The Party receiving the recommendation will have 60 days to review the associated documentation and either reject the proposed substance or accept the substance pending completion of appropriate procedural or domestic regulatory requirements. Cause for rejection must be documented and submitted to the initiating Party and may be the basis for any further negotiations.

3. The criteria to be applied to the selection of substances as candidates for listing in Appendix 1 are:

(a) Acute toxicological effects, as determined by whether the substance is lethal to:

(i) One-half of a test population of aquatic animals in 96 hours or less at a concentration of 500 milligrams per litre or less; or

(ii) One-half of a test population of animals in 14 days or less when administered in a single oral dose equal to or less than 50 milligrams per kilogram of body weight; or

(iii) One-half of a test population of animals in 14 days or less when dermally exposed to an amount equal to or less than 200 milligrams per kilogram body weight for 24 hours; or

(iv) One-half of a test population of animals in 14 days or less when exposed to a vapour concentration equal to or less than 20 cubic centimeters per cubic meter in air for one hour; or

(v) Aquatic flora as measured by a maximum specific growth rate or total yield of biomass which is 50 per cent lower than a control culture over 14 days in a medium at concentrations equal to or less than 100 milligrams per litre.

(b) Risk of discharge into the Great Lakes System, as determined by:

(i) Gathering information on the history of discharges or accidents;

(ii) Assessing the modal risks during transport and determining the use and distribution patterns;

(iii) Identifying quantities manufactured or imported.

4. Potentially hazardous polluting substances to be listed in Appendix 2 of this Annex shall be determined in accordance with the following procedures:

(a) Either Party may add new substances to Appendix 2 by notifying the other in writing that the substance is considered to be a potential hazard because of documented information concerning aquatic toxicity, mammalian and other vertebrate toxicity, phytotoxicity, persistence, bio-accumulation, mutagenicity, teratogenicity, carcinogenicity, environmental translocation or because of documented information on risk of discharge to the environment. The documentation of the potential hazard and the selected criteria upon which it is based will also be submitted.

(b) Removal of substances from Appendix 2 shall be by mutual consent of the Parties.

(c) The Parties shall give priority to the examination of substances listed in Appendix 2 for possible transfer to Appendix 1.

5. Programs and measures to control the risk of pollution from transport, storage, handling and disposal of hazardous polluting substances are contained in Annexes 4 and 8.

APPENDIX 1

HAZARDOUS POLLUTING SUBSTANCES

Acetaldehyde
Acetic Acid
Acetic Anhydride
Acetone Cyanohydrin
Acetyl Bromide
Acetyl Chloride
Acrolein
Acrylonitrile
Aldrin
Allyl Alcohol
Allyl Chloride
Aluminum Sulfate
Ammonia
Ammonium Acetate
Ammonium Benzoate
Ammonium Bicarbonate
Ammonium Bichromate
Ammonium Bifluoride
Ammonium Bisulfite
Ammonium Carbamate
Ammonium Carbonate
Ammonium Chloride
Ammonium Chromate
Ammonium Citrate, Dibasic
Ammonium Fluoborate
Ammonium Fluoride
Ammonium Hydroxide
Ammonium Oxalate
Ammonium Silicofluoride
Ammonium Sulfamate
Ammonium Sulfide
Ammonium Sulfite
Ammonium Tartrate
Ammonium Thiocyanate
Ammonium Thiosulfate
Amyl Acetate
Aniline
Antimony Pentachloride
Antimony Potassium Tartrate
Antimony Tribromide
Antimony Trichloride
Antimony Trifluoride
Antimony Trioxide
Arsenic Disulfide
Arsenic Pentoxide
Arsenic Trichloride
Arsenic Trioxide
Arsenic Trisulfide
Barium Cyanide
Benzene
Benzoic Acid
Benzonitrile
Benzoyl Chloride
Benzyl Chloride
Beryllium Chloride
Beryllium Fluoride
Beryllium Nitrate
Butyl Acetate
Butylamine
Butyric Acid
Cadmium Acetate
Cadmium Bromide
Cadmium Chloride
Calcium Arsenate
Calcium Arsenite
Calcium Carbide
Calcium Chromate
Calcium Cyanide
Calcium Dodecylbenzenesulfonate
Calcium Hydroxide
Calcium Hypochlorite
Calcium Oxide
Captan
Carbaryl
Carbon Disulfide
Chlordane
Chlorine
Chlorobenzene
Chloroform
Chlorosulfonic Acid
Chlorpyrifos
Chromic Acetate
Chromic Acid
Chromic Sulfate
Chromous Chloride
Cobaltous Bromide
Cobaltous Formate
Cobaltous Sulfamate
Coumaphos
Cresol
Cupric Acetate
Cupric Acetoarsenite
Cupric Chloride
Cupric Nitrate
Cupric Oxalate
Cupric Sulfate
Cupric Sulfate, Ammoniated
Cupric Tartrate
Cyanogen Chloride
Cyclohexane
2,4-D Acid
2,4-D Esters
Dalapon
DDT
Diazinon
Dicamba
Dichlobenil
Dichlone
Dichlorvos
Dieldrin
Diethylamine
Dimethylamine
Dinitrobenzene (mixed)
Dinitrophenol
Diquat
Disulfoton
Diuron
Dodecylbenzenesulfonic Acid
Endosulfan
Endrin
Ethion
Ethylbenzene
Ethylenediamine
EDTA
Ferric Ammonium Citrate
Ferric Ammonium Oxalate
Ferric Chloride
Ferric Fluoride
Ferric Nitrate
Ferric Sulfate
Ferrous Ammonium Sulfate
Ferrous Chloride
Ferrous Sulfate
Formaldehyde
Formic Acid
Fumaric Acid
Furfural
Guthion
Heptachlor
Hydrochloric Acid
Hydrofluoric Acid
Hydrogen Cyanide
Isoprene
Isopropanolamine Dodecylbenzenesulfonate
Kelthane
Lead Acetate
Lead Arsenate
Lead Chloride
Lead Fluoborate
Lead Fluoride
Lead Iodide
Lead Nitrate
Lead Stearate
Lead Sulfate
Lead Sulfide
Lead Thiocyanate
Lindane
Lithium Chromate
Malathion
Maleic Acid
Maleic Anhydride
Mercuric Cyanide
Mercuric Nitrate
Mercuric Sulfate
Mercuric Thiocyanate
Mercurous Nitrate
Methoxychlor
Methyl Mercaptan
Methyl Methacrylate
Methyl Parathion
Mevinphos
Mexacarbate
Monoethylamine
Monomethylamine
Naled
Naphthalene
Naphthenic Acid
Nickel Ammonium Sulfate
Nickel Chloride
Nickel Hydroxide
Nickel Nitrate
Nickel Sulfate
Nitric Acid
Nitrobenzene
Nitrogen Dioxide
Nitrophenol (mixed)
Paraformaldehyde
Parathion
Pentachlorophenol
Phenol
Phosgene
Phosphoric Acid
Phosphorus
Phosphorus Oxychloride
Phosphorus Pentasulfide
Phosphorus Trichloride
Polychlorinated Biphenyls
Potassium Arsenate
Potassium Arsenite
Potassium Bichromate
Potassium Chromate
Potassium Cyanide
Potassium Hydroxide
Potassium Permanganate
Propionic Acid
Propionic Anhydride
Pyrethrins
Quinoline
Resorcinol
Selenium Oxide
Sodium
Sodium Arsenate
Sodium Arsenite
Sodium Bichromate
Sodium Bifluoride
Sodium Bisulfite
Sodium Chromate
Sodium Cyanide
Sodium Dodecylbenzenesulfonate
Sodium Fluoride
Sodium Hydrosulfide
Sodium Hydroxide
Sodium Hypochlorite
Sodium Methylate
Sodium Nitrite
Sodium Phosphate, Dibasic
Sodium Phosphate, Tribasic
Sodium Selenite
Strontium Chromate
Strychnine
Styrene
Sulfuric Acid
Sulfur Monochloride
2,4,5-T Acid
2,4,5-T Esters
TDE
Tetraethyl Lead
Tetraethyl Pyrophosphate
Toluene
Toxaphene
Trichlorfon
Trichlorophenol
Triethanolamine Dodecylbenzenesulfonate
Triethylamine
Trimethylamine
Uranyl Acetate
Uranyl Nitrate
Vanadium Pentoxide
Vanadyl Sulfate
Vinyl Acetate
Xylene (mixed)
Xylenol
Zinc Acetate
Zinc Ammonium Chloride
Zinc Borate
Zinc Bromide
Zinc Carbonate
Zinc Chloride
Zinc Cyanide
Zinc Fluoride
Zinc Formate
Zinc Hydrosulfite
Zinc Nitrate
Zinc Phenolsulfonate
Zinc Phosphide
Zinc Silicofluoride
Zinc Sulfate
Zirconium Nitrate
Zirconium Potassium Fluoride
Zirconium Sulfate
Zirconium Tetrachloride

APPENDIX 2

POTENTIAL HAZARDOUS POLLUTING SUBSTANCES

Acridine
Allethrin
Aluminum Fluoride
Aluminum Nitrate
Ammonium Bromide
Ammonium Hypophosphite
Ammonium Iodide
Ammonium Pentaborate
Ammonium Persulfate
Antimony Pentafluoride
Antimycin A
Arsenic Acid
Barban
Benfluralin
Bensulide
Benzene Hexachloride
Beryllium Sulfate
Butifos
Cadmium
Cadmium Cyanide
Cadmium Nitrate
Captafol
Carbophenothion
Chlorflurazole
Chlorothion
Chlorpropham
Chromic Chloride
Chromium
Chromyl Chloride
Cobaltous Fluoride
Copper
Crotoxyphos
Cupric Carbonate
Cupric Citrate
Cupric Formate
Cupric Glycinate
Cupric Lactate
Cupric Paraamino Benzoate
Cupric Salicylate
Cupric Subacetate
Cuprous Bromide
Demeton
Dibutyl Phthalate
Dicapthon
2,4-Dinitrochlorobenzene
p-Dinitrocresol
Dinocap
Dinoseb
Dioxathion
Dodine
EPN
Gold Trichloride
Hexachlorophene
Hydrogen Sulfide
m-Hydroxybenzoic Acid
p-Hydroxybenzoic Acid
Hydroxylamine
2-Hydroxyphenazine-1-Carboxylic Acid
Lactonitrile
Lead Tetraacetate
Lead Thiosulfate
Lead Tungstate
Lithium Bichromate
Malachite Green
Manganese Chloride, Anhydrous
MCPA
Mercuric Acetate
Mercuric Chloride
Mercury
Metam-Sodium
p-Methylamino-Phenol
2-Methyl-Napthoquinone
Neburon
Nickel Formate
Phenylmercuric Acetate
n-Phenyl Naphthylamine
Phorate
Phosphamidon
Picloram
Potassium Azide
Potassium Cuprocyanide
Potassium Ferricyanide
Propyl Alcohol
Pyridyl Mercuric Acetate
Rotenone
Silver
Silver Nitrate
Silver Sulfate
Sodium Azide
Sodium 2-Chlorotoluene-5-Sulfonate
Sodium Pentachlorophenate
Sodium Phosphate, Monobasic
Sodium Sulfide
Stannous Fluoride
Strontium Nitrate
Sulfoxide
Temephos
Thallium
Thionazin
1,2,4-Trichlorobenzene
Uranium Peroxide
Uranyl Sulfate
Zinc Bichromate
Zinc Potassium Chromate
Zirconium Acetate
Zirconium Oxychloride

ANNEX 12

PERSISTENT TOXIC SUBSTANCES

1. Definitions. As used in this Annex:

(a) "Persistent toxic substance" means any toxic substance with a half-life in water of greater than eight weeks;

(b) "Half-life" means the time required for the concentration of a substance to diminish to one-half of its original value in a lake or water body;

(c) "Early warning system" means a procedure to anticipate future environmental contaminants (i.e., substances having an adverse effect on human health or the environment) and to set priorities for environmental research, monitoring and regulatory action.

2. General Principles.

(a) Regulatory strategies for controlling or preventing the input of persistent toxic substances to the Great Lakes System shall be adopted in accordance with the following principles:

(i) The intent of programs specified in this Annex is to virtually eliminate the input of persistent toxic substances in order to protect human health and to ensure the continued health and productivity of living aquatic resources and man's use thereof;

(ii) The philosophy adopted for control of inputs of persistent toxic substances shall be zero discharge.

(b) The Parties shall take all reasonable and practical measures to rehabilitate those portions of the Great Lakes System adversely affected by persistent toxic substances.

3. Programs. The Parties, in cooperation with the State and Provincial Governments, shall develop and adopt the following programs and measures for the elimination of discharges of persistent toxic substances:

(a) Identification of raw materials, processes, products, by-products, waste sources and emissions involving persistent toxic substances, and quantitative data on the substances, together with recommendations on handling, use and disposition. Every effort shall be made to complete this inventory by January, 1982;

(b) Establishment of close coordination between air, water and solid waste programs in order to assess the total input of toxic substances to the Great Lakes System and to define comprehensive, integrated controls;

(c) Joint programs for disposal of hazardous materials to ensure that these materials such as pesticides, contaminated petroleum products, contaminated sludge and dredge spoils and industrial wastes are properly transported and disposed of. Every effort shall be made to implement these programs by 1980.

4. Monitoring. Monitoring and research programs in support of the Great Lakes International Surveillance Plan should be established at a level sufficient to identify:

(a) Temporal and spatial trends in concentration of persistent toxic substances such as PCB, mirex, DDT, mercury and dieldrin, and of other substances known to be present in biota and sediment of the Great Lakes System;

(b) The impact of persistent toxic substances on the health of humans and the quality and health of living aquatic systems;

(c) The sources of input of persistent toxic substances; and

(d) The presence of previously unidentified persistent toxic substances.

5. Early Warning System. An early warning system consisting of, but not restricted to, the following elements shall be established to anticipate future toxic substances problems:

(a) Development and use of structure-activity correlations to predict environmental characteristics of chemicals;

(b) Compilation and review of trends in the production, import, and use of chemicals;

(c) Review of the results of environmental testing on new chemicals;

(d) Toxicological research on chemicals, and review of research conducted in other countries;

(e) Maintenance of a biological tissue bank and sediment bank to permit retroactive analysis to establish trends over time;

(f) Monitoring to characterize the presence and significance of chemical residues in the environment;

(g) Development and use of mathematical models to predict consequences of various loading rates of different chemicals;

(h) Development of a data bank for storage of information on physical/chemical properties, toxicology, use and quantities in commerce of known and suspected persistent toxic substances.

6. Human Health. The Parties shall establish action levels to protect human health from the individual and interactive effects of toxic substances.

7. Research. Research should be intensified to determine the pathways, fate and effects of toxic substances aimed at the protection of human health, fishery resources and wildlife of the Great Lakes Basin Ecosystem. In particular, research should be conducted to determine:

(a) The significance of effects of persistent toxic substances on human health and aquatic life;

(b) Interactive effects of residues of toxic substances on aquatic life, wildlife, and human health; and

(c) Approaches to calculation of acceptable loading rates for persistent toxic substances, especially those which, in part, are naturally occurring.

APPENDIX B

ENVIRONMENTAL MAPPING

A Plan of Recommended Action to the IJC Science Advisory Board
For Environmental Mapping Activities
To Address Issues of Concern and Provide Information To:

- Improve understanding of the Role of Man in the Great Lakes Ecosystem and Thus Our Ability to Manage the Resources in Keeping with the United States-Canada Water Quality Agreement; and,

- Assist in Great Lakes Planning and Management Decisions That Affect the Great Lakes Ecosystem.

April 1979

Task Force on Environmental Mapping
Science Advisory Board
International Joint Commission
Windsor, Ontario

TABLE OF CONTENTS

INTRODUCTION

The Task Force on Environmental Mapping was initiated by the Research Advisory Board at its 23rd meeting on September 20-21, 1977. The Draft Terms of Reference, Appendix A, were prepared by the Board, and the revised Terms of Reference, Appendix B, were prepared by the Task Force in January 1979. The Task Force was organized in January 1978 and held its first meeting in April 1978. Task Force membership is listed in the Membership List. Represented are various Canadian, United States, and international agencies with operational, research and development, and coordinating missions.

The Task Force has concluded that there are many ways in which environmental mapping may serve as a useful tool to further the goals of the Great Lakes Water Quality Agreement. The Task Force did not achieve consensus on what to map and for what audience. Alternatives are therefore presented and recommendations, therefore, include alternatives on what to map. Recommendations also address resources and organization.

WHY MAP?

Environmental mapping is a process of data analysis and communication. Information is organized and presented in the form of a document. It relies on an existing data base and expert interpretation. The product of environmental mapping can take the form of an atlas, an atlas monograph, or a brochure, depending upon the intended purpose, the audience, the adequacy of available data, and the complexity of the information to be documented and communicated. A document that contains primarily maps is called an atlas, while an atlas monograph contains a combination of maps, figures, tables, and text. Environmental mapping products were identified and discussed by participants of the Workshop on Environmental Mapping of the Great Lakes, (e.g., Cronin and Lippson (1976), the Chesapeake Bay of Maryland-Atlas of Natural Resources and Ginter (1976), New York Bight Atlas Monograph Series.) (See Rosenberger and Robertson, 1976).

Atlases of meteorological and physical oceanographic variables have been used extensively to portray statistical properties of the environment for engineering applications. More complete works relating to weather variables are called climatology. It follows that suitably designed, environmental mapping provides information of value to engineers, planners, managers, scientists, elected officials, and the general public. The content of environmental mapping depends upon the intended purpose, the audience, available data, the set of variables required (from amongst the physical, chemical, biological, and societal possibilities), and the relevant temporal and spatial scales. To the Task Force, environmental mapping is a process of data analysis that describes humanity in the Great Lakes ecosystem on topics of importance to the IJC, its institutions, participating agencies, local agencies, and the public.

The IJC plays a special role with respect to Great Lakes water quantity and quality as defined in the Treaty of 1909 and the Great Lakes Water Quality

Agreements of 1972 and 1978 by providing a forum in which Canadian and United States agencies achieve environmental goals and objectives. Environmental mapping has values that contribute to these goals and objectives:

1. It is a means by which regional perspectives are provided as a context for local decision making.

2. It is a means by which data and information derived from diverse sources and disciplines can be synthesized into a single format.

   a. Too much of the relevant information, e.g., data archives, reports, journal articles, is inaccessible to or inappropriately packaged for the users of such information: managers, planners, and the informed public.

   b. Much of the knowledge of the Great Lakes gained to date does not effectively develop and communicate an understanding of the interactions among biological, chemical, and physical factors and processes or between society and the Great Lakes, but rather addresses questions or problems within relatively narrow technical fields.

3. It provides an opportunity for the historical perspective to highlight areas of special concern requiring attention or to demonstrate achievements in ecosystem improvement.

   a. Particulary important is the role that historical data can play in revealing the former conditions of the Great Lakes ecosystem as an environment in which high value species of fish were abundant and in which full use of the resource for recreation and aesthetic enjoyment could occur.

   b. Development of trend lines from past to present permits people from a variety of backgrounds to make projections under various assumptions of what the future may hold.

4. It provides a mechanism for the identification of ecosystem problems, gaps in available data, or weaknesses in existing information.

5. It serves to coordinate and reorganize thinking about the problems of a complex ecosystem.

In summary, environmental mapping should be used by the International Joint Commission:

1. To improve understanding of the dynamics of the Great Lakes ecosystem and thus our ability to manage the resource in keeping with the Great Lakes Water Quality Agreement; and

2. To improve communications between scientists, managers, regulators, elected officials, and the general public on matters relating to the Great Lakes ecosystem.

Within the context of the United States-Canadian Great Lakes Water Quality Agreement and its relationship to public information, resource management, and planning, suitable goals for the IJC environmental mapping activity are to address issues of concern and to provide information:

1. To improve understanding of the Great Lakes ecosystem and the dynamic interrelationships involved among the biological, chemical, physical, and societal components of the environment; and

2. To assist in Great Lakes planning and management decisions that affect the Great Lakes ecosystem.

With these goals in mind, environmental mapping objectives are:

1. To synthesize and display knowledge of the Great Lakes ecosystem;

2. To provide perspective on societal activities stressing ecosystem quality;

3. To aid decision makers and an informed public to reach complementary decisions and to implement programs to achieve mutually agreeable management objectives under the Water Quality Agreement;

4. To deal with issues affecting the Great Lakes ecosystem, including past to present trends and potential future problems; and

5. To improve understanding of the Great Lakes ecosystem in order to develop a broader base of support for the actions required to achieve the goals.

WHAT TO MAP?

The Task Force has been faced with the question, "What to map and for what audience?" An examination of the Task Force terms of reference does not provide the answer. From one viewpoint, environmental mapping is a useful tool looking for a problem to solve.

Most of the Task Force discussions have concerned the definition of objectives - what to map and for what audience? Many suitable problems were identified for which an environmental mapping approach is applicable. Since we were unable to arrive at a consensus on the objectives, alternatives will be presented. The availability of resources to conduct environmental mapping may decide the final choice.

One environmental mapping alternative uses the problem-oriented approach to ecosystem quality. A series of topics was identified, including contaminants, other man-induced changes (e.g., water withdrawals), and components of Great Lakes resources (e.g., fisheries). Environmental mapping activities will be described for two of these topics-toxic contaminants and eutrophication. The objectives relate to improving an understanding of the cause and effect relationships in the Great Lakes ecosystem and providing an aid to assist decision makers and planners and to raise the awareness of elected officials and the public to these problems, possible solutions, and the effects of remedial measures. A broad audience would benefit.

A second major alternative for environmental mapping follows the concept-oriented approach of Great Lakes rehabilitation. The objective is to improve public understanding of the problems associated with rehabilitation and to achieve public support for such a program.

TOXIC CONTAMINANTS

Background

The organizing principle for the problem-oriented approach involves man in the ecosystem. For selected classes of contaminants, there is a causal chain, starting with human settlement, growth, and development of the drainage basin and ending with the effects on the lakes, the impact on human uses, and corrective actions taken by environmental management. Five elements are considered:

1. The drainage basin - human settlement, development, and manipulation of the basin that results in contaminant sources and natural conditions;

2. Loads to the Great Lakes;

3. Lake effects;

4. Societal and use effects; and

5. Corrective actions or implemented remedial measures.

The fifth element, corrective actions or implemented remedial measures, synthesizes the first four elements in terms of changes to the drainage basin, to loads, to lake effects, and to societal and use effects. Relevant space and time scales need to be considered and the most suitable variables included. The environmental mapping design for each topic involves compromise between simple concise communications of most relevant information and the desire to portray the interdependent ecosystem aspects of the problem.

Toxic contaminants have been identified as a class of important issues that impact Great Lakes ecosystem quality. Toxic contaminants are cited in the 1978 Great Lakes Water Quality Agreement in Annex 1 - Specific Objectives, Annex 10 - Hazardous Polluting Substances, and Annex 12 - Persistent Toxic Substances. Of these three Annexes, Annex 12 is particularly relevant to environmental mapping. In addition to establishing general principles for regulation strategies and programs for the elimination of persistent toxic substance discharges, Annex 12 addresses monitoring to identify temporal and spatial trends, and research to determine pathways, fate, and effects of toxic substances. The data and information synthesis of environmental mapping for selected toxic contaminants will provide a basis for improved decisions to ameliorate problems that affect the Great Lakes ecosystem. Data and information are spread through agency files and reside in scattered research projects and are very inaccessible.

With respect to the feasibility of mapping toxic contaminants, data sources are good for the whole lake scale, especially Lake Ontario (Ontario Ministry of Natural Resources (OMNR), Ontario Ministry of the Environment (MOE), New York Department of Environmental Conservation (NYDEC), Fisheries Inspection Board, IJC, EPA, etc. Data problems may be encountered at the site specific scale. Data availability will be the determining factor in environmental mapping. Data will be available from experimental studies such as Pollution From Land Use Activities Reference Group (PLUARG), Upper Lakes Reference Group (ULRG), etc., and from federal, provincial, and state agencies.

Objectives

The objectives of the mapping of toxic contaminants are:

1. To synthesize present information and provide clearer understanding of the materials and processes of the ecosystems;

2. To improve understanding on the part of the public, elected officials, and government agencies;

3. To aid decision makers and an informed public in implementing programs to reach mutually agreeable management objectives under the Water Quality Agreement;

4. To provide a basis for lakewide (ecosystem) management strategies for the protection and enhancement, as well as the development and use, of the resources;

5. To identify data, information, and knowledge gaps; and

6. To serve as a planning tool for future work by providing analyzed baseline and trend data and information.

Approach

Four toxic contaminants: i.e., mercury, PCB, mirex, and possibly lead; are considered suitable for environmental mapping because the information base should be adequate to permit a meaningful mapping endeavor. The mapping approach will include information on sources, levels of contaminants in the ecosystem and effects of contaminants on the ecosystem and human uses. A preliminary outline is of the following form:

Map Past, Present, And Potential Sources Of Hg, PCB, Mirex, Lead (i.e., input mapping)	Map Level Of Contaminants In	Effects Of Contaminants On The Ecosystem
Point Sources Of Pollution - combined storm sewers - municipal sewage - industrial effluent (by type of industry) - power plants: nuclear fossil	- water - sediment - invertebrates - fish - wildlife (e.g., herring gulls)	- sensitive areas - pathways of contaminants through the food chain and the environment in general
Non-Point Sources Of Pollution - tributary loadings - ground water - agricultural runoff - urban runoff - air - dredging - oil and gas exploration - spills - watercraft wastes - lake bottom sediments - erosion - solid and liquid waste disposal		**Effects On Human Uses;** - commercial fisheries - recreation - water supply - power generation - industrial - agricultural

Where possible, information will be included on the historical development of the important contaminant issues.

Two mapping scales are envisaged:

1. Total Great Lakes, such as the Great Lakes Water Use Map; and,

2. Site specific (i.e., nearshore), concentrating on problem areas such as Hamilton Harbor, Toronto Harbor, the Bay of Quinte, and the Niagara River.

To be of value, the mapping effort must be seen as a continuing process, with trend updates occurring every 5 years or so.

An example of available mapping information on mercury, lead, and PCB concentrations in sediments is contained in Figures 1, 2, and 3.

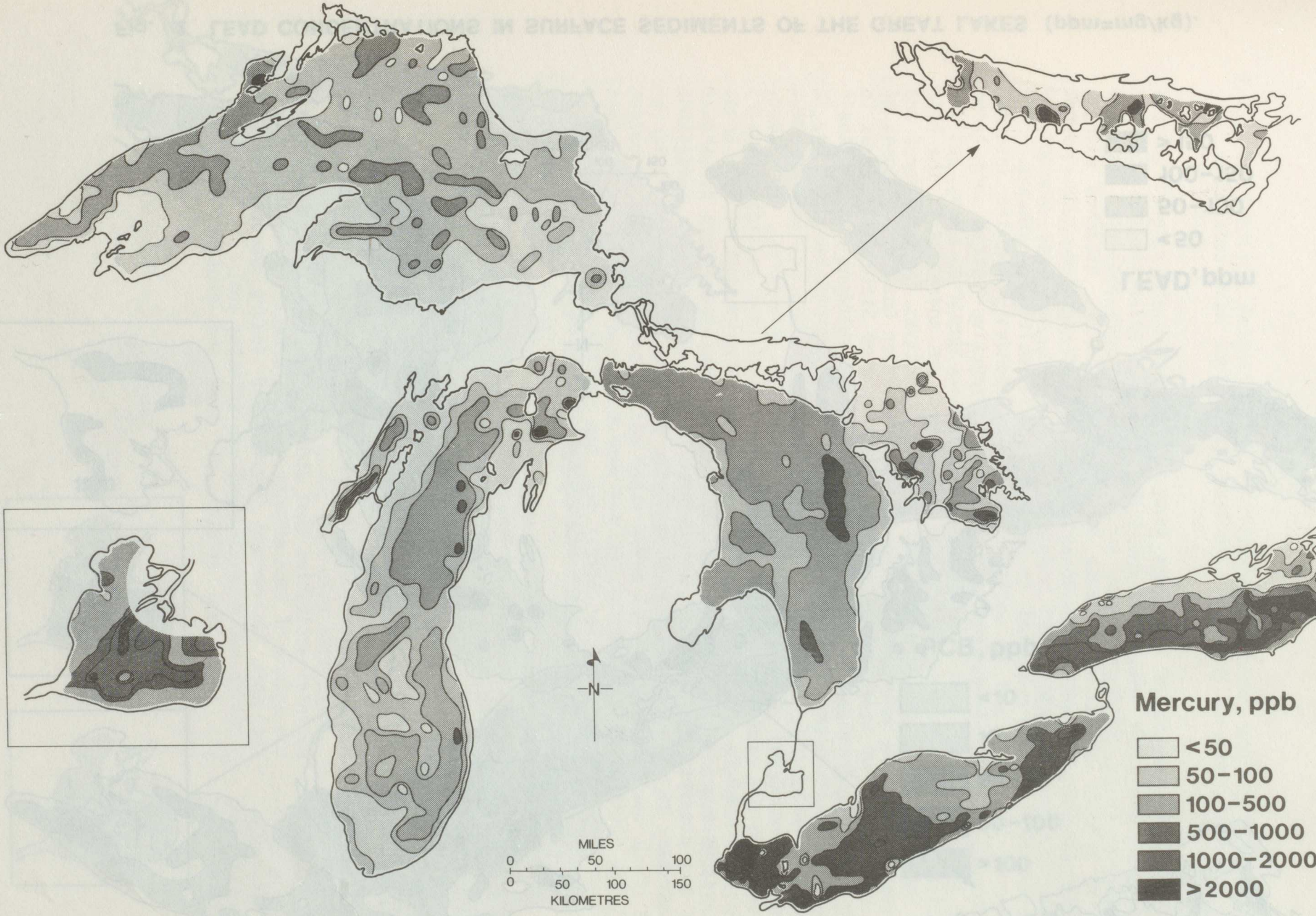


Fig. 1 MERCURY CONCENTRATIONS IN SURFACE SEDIMENTS OF THE GREAT LAKES (ppb = µg/kg).

Fig. 2 LEAD CONCENTRATIONS IN SURFACE SEDIMENTS OF THE GREAT LAKES (ppm=mg/kg).

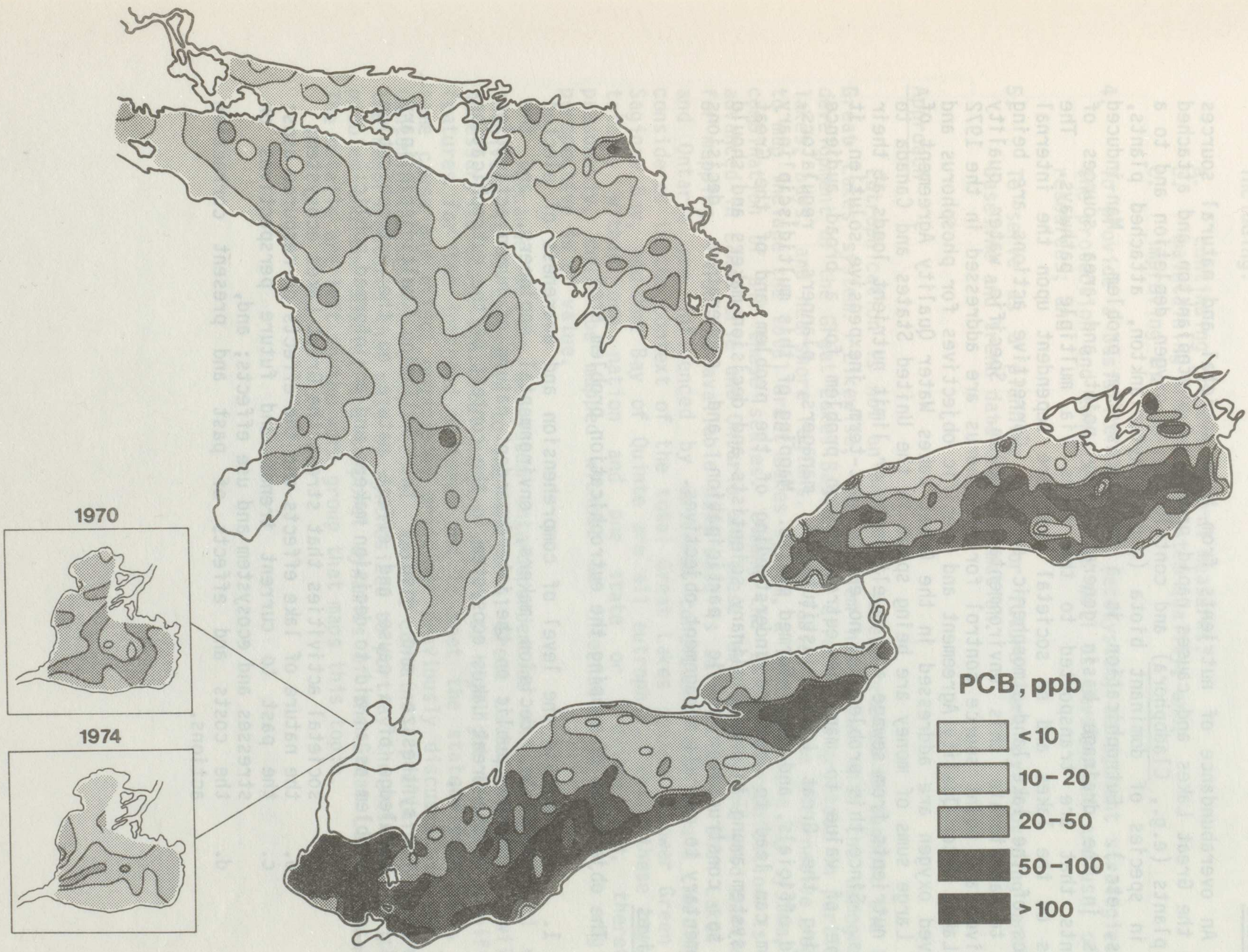


Fig. 3 PCB CONCENTRATIONS IN SURFACE SEDIMENTS OF LAKES HURON, ERIE AND ONTARIO. (ppb=μg/kg)

EUTROPHICATION

Background

An overabundance of nutrients from both societal and natural sources enters the Great Lakes and causes rapid growth of phytoplankton and attached water plants (e.g., Cladophora) and contributes to oxygen depletion and to a shift in species of dominant biota (e.g., phytoplankton, attached plants, benthos, etc.). Eutrophication is a true ecosystem problem. Man-induced changes in the drainage basin generate many point and area sources of nutrients that are transported to the lakes via multiple pathways. The effects on the lakes and on societal uses are dependent upon the internal dynamics of the lake-land-atmospheric system. Corrective actions are being taken to ameliorate this environmental problem. Specific water quality objectives and point source control for phosphorus are addressed in the 1972 Great Lakes Water Quality Agreement and specific objectives for phosphorus and dissolved oxygen are addressed in the Great Lakes Water Quality Agreement of 1978. Large sums of money are being spent in the United States and Canada to remove nutrients from sewage and to eliminate or limit nutrient loads at their sources. Since this problem has no easy, short-term, inexpensive solution, it will be of value to map the eutrophication problem for a broad audience including the Great Lakes institutions, managers, planners, regulators, elected officials, and the informed public. Mapping of this multidisciplinary problem can lead to improved understanding of the problem and of the Great Lakes system among interdisciplinary scientists and decision makers and should lead to constructive public participation and cooperative decisions complementary to overall management objectives.

Objectives

The objectives of mapping the eutrophication problem are:

1. To increase the level of comprehension and awareness of elected officials, decision makers, environmental engineers, and the informed public on the interdependent nature of human activities in the Great Lakes ecosystem in the context of the eutrophication problem;

2. To synthesize and display the following multidisciplinary knowledge of a cause and effect nature on the eutrophication problem as an aid to decision makers and an informed public:

    a. societal activities that stress the Great Lakes ecosystem;
    b. the nature of lake effects and the effects on resource uses;
    c. the past to current trends and future perspectives on stresses and ecosystem and use effects; and,
    d. the costs and effects of past and present corrective actions.

3. To identify potential future ecosystem-related quality and effects associated with various alternative strategies of corrective actions, including:

   a. continuing present control measures;
   b. maintaining present ecosystem quality; and,
   c. improving the quality.

4. To provide a basis for lakewide (ecosystem) management strategies for the protection and enhancement, as well as development and use, of the resources; and

5. To serve as a planning tool for future work by providing analyzed baseline and trend data and information.

Approach

Eutrophication is not an uniformly severe problem throughout the total Great Lakes system. Likewise, the problem has grown with the demographic development of the Great Lakes Basin. The effects are greatest in particular lakes, bays, and nearshore regions. (See Table 1.) The alternative regions to map include the total Great Lakes system, a lake system, a bay system, or a combination of all these scales. Among the lakes, eutrophication is most advanced in Lakes Erie and Ontario and these lake systems are good candidates for mapping. Also the available data base is satisfactory. Both Lakes Erie and Ontario are influenced by upstream conditions and should ideally be considered in the context of the total Great Lakes system. Lower Green Bay, Saginaw Bay, and the Bay of Quinte are all eutrophic. While these bays are totally within one nation and one state or province and, therefore, presumably, could be mapped without an international effort, a regional perspective is of value.

Because of the ecosystem interdependencies and multipolitical units involved, it is desirable to map the total Great Lakes system. It will be necessary to scale the total mapping effort to highlight the most significant features for the intended audience and to meet the stated objectives. The same cause and effect organizing principle previously discussed in the Toxic Contaminants section is applicable. Table 2 contains a preliminary outline of the major features that must be synthesized to portray the nutrient enrichment problem and the spatial and temporal dynamics of the Great Lakes ecosystem. The details are left to the work group that maps this topic.

Table 1

Status of Eutrophication in Particular Great Lakes Regions

Lake	Bay	OLIGO*	OLIGO/MESO	MESO*	MESO/EUTRO	EUTRO*
Superior		X				
Huron		X				
	Saginaw					X
Michigan			X			
	Lower Green					X
Erie					X	X
Ontario					X	
	Quinte					X

*OLIGO - oligotrophic
MESO - mesotrophic
EUTRO - eutrophic

Table 2

Eutrophication Outline

I.	Introduction a. The Great Lakes system b. The problem
II.	The Drainage Basins a. Domestic sources (population, treatment, etc.) b. Land sources (land use, soils, fertilizer use, etc.) c. Pathways (water, air)
III.	Loadings a. Phosphorus b. Nitrogen c. Silicon
IV.	The Lakes a. Physical environment (lake levels and flows, temperature, transparency, etc.) b. Chemical response (phosphorus, oxygen, etc.) c. Biology (phytoplankton, benthos, macrophytes, etc.)
V.	Societal Effects a. Water supply b. Fisheries c. Recreation and aesthetics d. Water quality management (corrective actions and effects)

REHABILITATION

Why?

During the past 200 years (and in particular the past 50 years), human activities in the Great Lakes Basin have caused an increasing degradation of the ecosystem our forebearers knew. Today, we are most widely aware of problems arising from cultural eutrophication, the presence of toxic substances, and great changes in fish populations.

In recognition of the alarm with which continued degradation of the Great Lakes has been viewed, current management practices attempt to limit further deterioration of the upper lakes and to improve water quality in the lower lakes by defining acceptable concentrations of chemical and microbiological constituents (water quality objectives). The limited success of these management practices encourages the view that it is both technically and economically feasible to reverse the process of water quality degradation. In recognition of this, research has already begun to assess environmental sensitivity, or to put it more bluntly, "to see if it is possible to state what wastes may be safely disposed of or released into the Great Lakes, how much, and where."

At this point, another concept can be introduced into this evolution of human appreciation of the environment, that of rehabilitation of the natural ecosystem/environment.

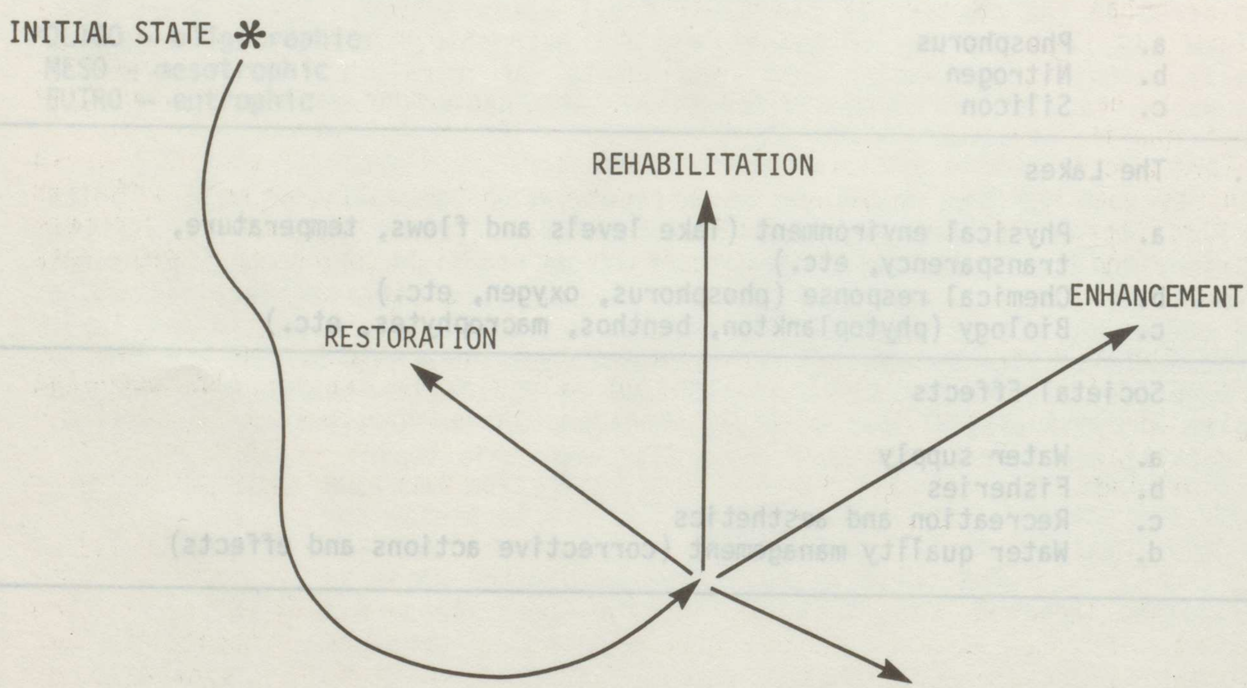


Figure 4. Diagrammatic representation of the meaning of some words (Regier, 1978).

The following narrative (Regier, 1978) expands on the diagrammatic representation in Figure 4.

Restoration would take us back in a rather direct route toward the initial state, presumably accepting undesirable features of the initial natural state as part of the overall package. Of course, any thorough-going restoration is impossible, -- it is at most a matter of degree.

Further degradation more or less consistent with the degradative process of the past two centuries, would lead in the opposite direction to that of restoration.

Enhancement that seeks to improve upon the current state of an ecosystem without reference to its initial state, might lead an ecosystem further from the initial state, say by contributing desirable man-made features and suppressing undesirable natural features.

Rehabilitation may be defined as a pragmatic mix of non-degradation, enhancement, and restoration. To the extent that natural ecosystemic healing can be fostered, restoration of some desirable features should prove a cost-effective tactic within such a mix.

From the above, the Task Force envisioned that rehabilitation means the improvement of degraded conditions and the possible use of enhancement to develop a useful, desirable, and largely self-sustaining biological community, which may be exemplified by a healthy, desirable (from a human use point of view), and vigorous fish population. Rehabilitation does not mean a reversal to original environmental conditions (restoration), which is clearly impossible; it really means "being a little ahead of the game."

It has been difficult enough to achieve the present improved status of water quality in the Great Lakes, and it will be much more difficult to achieve successful rehabilitation. In particular, a rehabilitation program requires not just an acceptance of the concept but a public understanding of the problems which are to be faced, an ability and willingness to address issues directly, and an active and continuing public support for management actions designed to advance the concept of rehabilitation.

The Task Force believes that the idea of environmental mapping can be used as a very powerful tool by which public understanding, involvement, and it is hoped, support for a Great Lakes rehabilitation program can be mobilized and sustained. The following presentation has been developed, therefore, with this in mind: the underlying objective is one of rehabilitation.

How?

The term environmental mapping, as used by the Task Force in the context of the rehabilitation program, would involve presentation of information in a predominantly visual form, based upon the synthesis of existing Great Lakes environmental data. The information will be designed to illustrate cause and effect relationships with respect to human activities in the basin (including socio-economic aspects), the concept of ecosystem inter-relationships, some of the options that lie ahead (possible costs and time frames), and projected results arising from management actions. Information will be presented as maps, diagrams, graphic plots, tables, pictures, photographs, and commentary.

It is not intended to present a complex and exhaustive series of distribution maps and diagrams descriptive of the many hundreds of variables already measured and recorded in the Great Lakes Basin. Rather, the presentation will be used to illustrate the development of a theme, namely rehabilitation, and the nature and magnitude of problems which may be encountered on the way (technical, socio-economic, and political) and to characterize what may or may not happen as a result of both individual and group actions.

What?

It is suggested that the presentation of information may be organized into the following three parts:

1. A comparison of past and present conditions of the Great Lakes ecosystem;

2. An explanation of why changes have occurred and how the causes are related to human activities in the Basin; and,

3. Management response (what has been done), and future options.

Part I

Historic data are limited and presentations will rely heavily on trends, spot records, maps of harbor and shoreline changes, etc. Information, for example, should be used to illustrate changes in fish populations and in water quality (including perhaps sediment core data for nutrient elements, trace metals, persistent organics, and recent fossil material).

Display will be heavily dependent upon the availability of data.

Part II

This will draw predominantly upon the work of the past two decades, during which time distributions (space/time) and causative relationships have been intensively studied. The following outline of example content addresses the question, Why the Changes?

Loss of Habitat	-spawning -nursery	water level regulations, land use/stream use changes, bank vegetation changes, hydrograph and temperature regime changes, and sediment load changes.

Overfishing - (details to be added by future environmental mapping work groups).

Biological stressors - sea lamprey, smelt, alewife, critical mass.

Unanswered questions - (details to be added by future environmental mapping work groups).

Climatic variables - water levels at critical periods, temperature/ hatch success, food supply, flow through and dissolved oxygen (D.O.) levels, and species changes.

Food supplies - impact of eutrophication, D.O. depletion, and species changes.

Toxic substances - Lethal and sublethal effects, and tainting. Material pathways, degradation, availability, and biotransformation.

Different types of mixing for different contaminants (sinks/storage/release).

Exposure time.

Biomagnification.

Migration barriers - Dams, constructions, thermal plumes, and entrainment.

Changes in Great Lakes water quality and fisheries have been caused by various interactions of the above factors. The examples from within the Great Lakes Basin will be portrayed and explained.

Part III

In any form of biological rehabilitation, it is essential to recognize that appropriate water quality conditions are a prerequisite. In this light it is important to show achievements of recent management activities, i.e., lake response to reduced loadings, the loading concept, the different sources and the ability to control the sources, and the costs. Rehabilitation requires that we build upon this initial achievement. In terms of loadings alternative future options include:

1. Spread the load around (dilution solution to pollution),

2. Allow continued excess in limited areas (limited use zones), and

3. Have a goal to reduce both total and point loads over the long-term.

In fact, with demophoric growth, it is necessary to achieve increasingly better levels of effluent control (contaminant removal) since increased discharge volumes require decreased concentration just to maintain the same total load.

Management actions and public appreciation must recognize:

- that almost no part of the Great Lakes ecosystem remains unaffected by cultural activities;
- that "interconnectedness" within the ecosystem ensures that the impact of cultural activities penetrates to a considerable depth within the system;
- that much of the Great Lakes environment responds like a "riverine" system in which downstream effects are very important;
- that synergistic relationships negate options of "spreading the loads around";
- that there is uncertainty in our predictions/projections because many questions remain unanswered (or data are not available);
- that there is, further, the uncertainty principle because we are dealing with a dynamic system in which no part of the environment can be written off as non-essential.

Using present information, project to show "maybe-costs" to achieve desirable water quality standards for rehabilitation with existing technology.

Explore options.

Describe socio-political structure in basin and managerial organization.

Consider the pros and cons in terms of the impacts of possible management decisions and point to uncertainties and, as yet, unanswered questions.

Comment

In presenting rehabilitation in this way, the resulting document should be designed to offer the public a hope for realistic improvements and to provide a long-term goal, in support of which technical developments can be encouraged and against which progress can be compared.

PROS AND CONS

The selection of which topic (or topics) to map and for what audience is dependent upon the importance of the objective and the availability of resources. Agency interest has been expressed (but not to the point of financial commitment) as follows:

Option A - Toxic Contaminants: Ontario Ministry of the Environment (MOE), Environmental Protection Agency (EPA), National Oceanic and Atmospheric Administration (NOAA)

- Eutrophication: NOAA

Option B - Rehabilitation: National Water Research Institute (NWRI), Ontario Ministry of Natural Resources (OMNR), Fish and Wildlife Service (FWS), Great Lakes Fishery Commission (GLFC).

Consideration of the pros and cons of these alternatives is of interest.

Option A

PROS

1. The stated objectives for environmental mapping of toxic contaminants and eutrophication are of considerable importance. (See pages 7, 12 and 14).
2. The form of presentation is generally aligned with the existing missions of operating agencies.
3. The content and treatment of information conforms more to the scope of present thinking, and information will be organized in a holistic or ecosystem cause and affect framework.
4. By using a generally-agreed-to framework, participants could work (largely) independently, each, as it were, prefabricating a separate "plug-in" information block. Such an approach could do much to ease the organization of the work.
5. Completion of the task will provide an analyzed baseline and trend data and information that can be updated as necessary, at regular intervals (e.g., every 5 years), and can be used as a valuable reference source.
6. There is agency interest in support of this option.

CONS

1. This option may be thought of as, in part, "self-serving", with respect to the interests of supporting agencies.
2. With the weight of data available, and the depth to which they could be addressed, there is a design problem relating to what constitutes detail relevant to achievement of the objectives; the ecosystem concept could be lost with excessive detail.
3. Since Option A addresses more topics, it may take longer to complete and cost more than Option B.
4. One may question the benefits accruing from this option vs. costs incurred since a substantial volume of synthesized and partly synthesized Great Lakes data exists (although not organized via an environmental mapping approach to achieve the stated objectives).

Option B

PROS

1. This is a publicly oriented document with a well-defined intent, supportive of the concept of Great Lakes rehabilitation.

2. It provides a powerful means of presenting the ecosystem concept.

3. It is intended to evoke new and constructive thinking by the public at large, which includes managers and scientists, as well as the lay public.

4. The holistic viewpoint of Option B presents Great Lakes data in a new way.

5. It is likely that time and dollar requirements will be less for Option B than for Option A, although this depends upon both the depth of subject treatment and the ability to substantiate points made in Option B.

6. Work on this option will make particularly good use of the international cooperation provided under the aegis of the IJC.

CONS

1. There is not complete support for the concepts expressed in Option B, even within the IJC.

2. It will be more difficult to prepare the material for Option B, which places greater demand for input upon senior members of the scientific community (where depth of knowledge and overview have been gained by years of experience).

3. The preparation of material for Option B will require a team approach right from the start (the preparation of "plug-in" information blocks by individual agencies will not work for the most part), and it may be difficult to organize this because of various administrative constraints.

4. Although the concepts introduced in Option B should stand for some time, the immediate value of supporting data may not last as long as the in-depth reference material prepared for Option A.

5. By the definition of its approach, Option B cannot provide a satisfactory medium for the exchange of information within the scientific community; it can display only a very small portion of the data that are already available.

RECOMMENDATIONS

To Map or Not to Map? and What to Map?

The IJC plays a special role with respect to Great Lakes water quality and water quantity. It is in essence a broker bringing the various United States and Canadian agencies together to work on common objectives and to develop and implement cooperative programs. The goals and objectives of the Great Lakes Water Quality Agreement will be served by an environmental mapping activity under the aegis of the IJC. Therefore:

1. It is recommended that the IJC endorse an environmental mapping activity on topics considered important and for which resources can be made available.

A variety of topics and associated objectives are of value and of importance to the Great Lakes. From amongst a much larger number, the Task Force has presented three alternative topics and objectives, i.e., toxic contaminants, eutrophication, and rehabilitation. Due to differing perceptions among Task Force members and differing agency missions and policies, consensus was not reached on the desirability of pursuing these three topics even though each had its strong proponents. Nevertheless, mapping of each topic, in its separate way, would be of value to Great Lakes water quality and effort is contingent upon the availability of resources.

2. It is recommended that the IJC initiate an environmental mapping activity on one or more of the topics toxic contaminants, eutrophication, and rehabilitation.

Resources

The feasibility of an environmental mapping activity is related to the availability of resources (agency staff plus dollars). An estimate of the New York Bight Synthesis volume is $125K, including 1,000 copies of hardbound text, although this does not include total costs since it builds upon the availability New York bight monograph series. Based upon this figure, an estimate of the cost for a toxic contaminant or eutrophication atlas is $250K over a 2-year period, and maybe less for a rehabilitation atlas. While no firm commitments have been solicited, interest in supporting environmental mapping activities has been expressed by the following U.S. agencies: EPA, NOAA, FWS, and Canadian agencies: NWRI, MOE, OMNR.

3. It is recommended that the IJC solicit from the principal United States and Canadian agencies both interest and an indication of available resources to conduct environmental mapping on the topics and objectives indicated in recommendation 2.

Organization

The terms of reference of this Task Force (Appendices A and B) address broad aspects of environmental mapping as it may be of value to the IJC and to Great Lakes water quality. The Task Force membership was organized to carry out this charge. This task has been completed. A different membership is desirable to carry out mapping activities.

4. It is recommended that the Task Force on Environmental Mapping be discharged.

Contingent upon the concurrence of the Science Advisory Board (SAB) in recommendations 1 and 2, the concurrence of the IJC in recommendation 3, and the identification of suitable resources for environmental mapping,

5. It is recommended that a work group be established for each topic to be mapped from among the agencies that would contribute resources to conduct environmental mapping of that topic.

REFERENCES

Berg, N.A. and M.G. Johnson, 1978. Environmental Management Strategy for the Great Lakes System. Windsor, Ontario: International Joint Commission, International Reference Group on Great Lakes Pollution from Land Use Activities, pp. 31, 35, and 41.

Cronin, L.E. and A.J. Lippson, 1976. Chesapeake Bay and Potomac River. In: Proceedings of Workshop on Environmental Mapping of the Great Lakes, eds. D.R. Rosenberger and A. Robertson, pp. 59-65. Windsor, Ontario: International Joint Commission, Research Advisory Board.

Ginter, J.C., 1976. Atlas Making: The New York Bight Experience. In: Proceedings of Workshop on Environmental Mapping of the Great Lakes, eds. D.R. Rosenberger and A. Robertson, pp. 79-90. Windsor, Ontario: International Joint Commission, Research Advisory Board.

Regier, H.A., 1978. Introduction. In draft Feasibility Study: Great Lakes Ecosystem Rehabilitation and Restoration. Ann Arbor, Michigan: Great Lakes Fishery Commission (to be published).

Rosenberger, D.R., and Robertson, A., eds, 1976. Proceedings of Workshop on Environmental Mapping of the Great Lakes. Windsor, Ontario: International Joint Commission, Research Advisory Board, 224 pp.

APPENDIX A

DRAFT TERMS OF REFERENCE
OF GREAT LAKES RESEARCH ADVISORY BOARD
TASK FORCE ON ENVIRONMENTAL MAPPING OF THE GREAT LAKES
(SEPTEMBER 1977)

Task Force Objectives

The objectives of the Task Force are to develop a Plan of Study for Great Lakes environmental mapping. The Plan of Study will define:

- those dimensions which lend themselves to mapping;
- the scope of future mapping efforts;
- the agencies which should participate; and
- the anticipated costs.

To achieve the objectives of the Plan of Study;

The Task Force will examine alternative environmental mapping strategies and design, and lead a pilot study to determine the cost/benefits, the potentials, and the liabilities of such efforts, as a basis for future mapping.

Time Frame

The recommendations for design of the pilot study and selection of a pilot site should be completed by April 30, 1978. The completed pilot study will be submitted to the Research Advisory Board by April 20, 1980.

Resources Required for Task Force

Secretarial support from the IJC Regional Office is desirable. A budget of $5,000 is estimated to cover travel and printing of interim reports. Printing and development costs of the final report cannot be estimated until format is decided upon.

APPENDIX B

DRAFT TERMS OF REFERENCE
(JANUARY 29, 1979)

IJC's Science Advisory Board Task Force on Environmental Mapping of the Great Lakes.

From October 1977 to April 1979

The Task Force will develop a Plan to include:

- those dimensions which lend themselves to mapping;
- the rationale for mapping the scope of future mapping efforts; and
- the agencies which should participate.

The Task Force will make a complete interim report to the Board in April 1979.

MEMBERSHIP LIST

1978–1979

SCIENCE ADVISORY BOARD

- EXPERT COMMITTEES
- TASK FORCES
- SPECIAL COMMITTEES

GREAT LAKES SCIENCE ADVISORY BOARD

UNITED STATES SECTION

Dr. Donald I. Mount (Chairman)
Director
Environmental Research Laboratory - Duluth
Duluth, Minnesota

Mr. John J. Convery
Director
Wastewater Research Division
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio

Dr. Joseph Kutkuhn
Director
U.S. Department of the Interior
Fish and Wildlife Service
Great Lakes Fishery Laboratory
Ann Arbor, Michigan

Dr. Robert Ragotzkie
Director
Sea Grant College Program
University of Wisconsin
Madison, Wisconsin

Dr. John R. Sheaffer
President
Sheaffer and Roland, Inc.
Chicago, Illinois

Dr. Anne Spacie
Assistant Professor
Department of Forestry and Natural Resources
Purdue University
West Lafayette, Indiana

Dr. Virginia L. Prentice
Director
Sigurd Olson Institute
Northland College
Ashland, Wisconsin

Dr. Mitchell R. Zavon
Medical Director
Hooker Chemicals
Niagara Falls, New York

EX OFFICIO MEMBERS

Great Lakes Fishery Commission
Mr. Carlos M. Fetterolf, Jr.
Executive Secretary
Great Lakes Fishery Commission
1451 Green Road
Ann Arbor, Michigan

International Association for Great Lakes Research (IAGLR)
Dr. J. H. Leach *(Effective June 1978)*
Research Scientist
Lake Erie Fisheries Research Station
Fish & Wildlife Research Branch
Ministry of Natural Resources
Wheatley, Ontario NOP 2PO

GREAT LAKES SCIENCE ADVISORY BOARD

CANADIAN SECTION

Dr. G. K. Rodgers (Chairman)
Director *(Effective December 1978)*
National Water Research Institute
Canada Centre for Inland Waters
Burlington, Ontario

Dr. A. R. LeFeuvre (Chairman)
(Until December 1978)
Special Advisor
IJC Obligations & Research
Ontario Region, Inland Waters Directorate
Environmental Management Service
Burlington, Ontario

Dr. James H. Day
Department of Medicine
Queens University
Kingston, Ontario

Mr. Paul D. Foley
Coordinator, Development & Research Group
Pollution Control Branch
Ontario Ministry of the Environment
Toronto, Ontario

Mrs. F. Edna Gardner
Director, Metropolitan Toronto
and Region Conservation Foundation
Downsview, Ontario

Professor J. Llamas
Director, Water Resources Center
Faculty of Science and Engineering
University of Laval
Ste. Foy, Quebec

Mr. J. Douglas Roseborough
Director, Wildlife Branch
Ontario Ministry of Natural Resources
Queen's Park, Parliament Building
Toronto, Ontario

Dr. G. H. Tomlinson, II
Senior Research Advisor
Domtar Limited
Montreal, Quebec

Dr. J. R. Vallentyne
Senior Scientist
Fisheries and Marine Service
Ontario Region
Canada Centre for Inland Waters
Burlington, Ontario

Secretariat Responsibilities
Mr. Robert E. White
Senior Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
EXPERT COMMITTEE ON
ECOLOGICAL AND GEOCHEMICAL ASPECTS OF GREAT LAKES WATER QUALITY

Dr. David W. Schindler (Chairman)
Program Leader, Experimental Lakes Program
Freshwater Institute
Winnipeg, Manitoba

Dr. George C. Becking
Chief, Environmental Toxicology Division
Department of National Health and Welfare
Environmental Health Centre
Ottawa, Ontario

Mr. W. Jack Christie
Director, Fisheries Research Station
Ontario Ministry of Natural Resources
Picton, Ontario

Dr. G. Wolfgang Fuhs
Director, Environmental Health Center
Division of Laboratories and Research
N.Y. State Department of Health
Albany, New York

Dr. George Hendrey *(Effective November 1978)*
Dept. of Energy and Environment
Brookhaven National Laboratory
Upton, Long Island, New York

Dr. James R. Kramer
Professor of Geochemistry
Department of Geology
McMaster University
Hamilton, Ontario

Dr. Clifford H. Mortimer
Distinguished Professor of Zoology
University of Wisconsin-Milwaukee
Milwaukee, Wisconsin

SAB Liaison Member
Dr. J. R. Vallentyne
Senior Scientist
Fisheries and Marine Service
Ontario Region
Canada Centre for Inland Waters
Burlington, Ontario

Secretariat Responsibilities
Mr. David R. Rosenberger
Biologist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
EXPERT COMMITTEE ON
ENGINEERING AND TECHNOLOGICAL ASPECTS OF GREAT LAKES WATER QUALITY

Dr. James W. Patterson
(Chairman until November 1978)
Professor and Chairman
Pritzker Department of
Environmental Engineering
Illinois Institute of Technology
Chicago, Illinois

Dr. Norman W. Schmidtke
(Chairman Effective February 1979)
Acting Director
Wastewater Technology Centre
Department of the Environment
Canada Centre for Inland Waters
Burlington, Ontario

Dr. Wes W. Eckenfelder
Distinguished Professor of Environmental and Water Resources Engineering
Vanderbilt University
Nashville, Tennessee

Dr. Peter A. Krenkel
Executive Director
Water Resources Center
Desert Research Institute
University of Nevada System
Reno, Nevada

Dr. G. Fred Lee
Professor of Civil Engineering
Engineering Research Center
Colorado State University
Fort Collins, Colorado

Dr. Cecil Lue-Hing
Director, Research and Development
Metropolitan Sanitary District - Greater Chicago
Chicago, Illinois

Special Appointee
Mr. Carl Schafer
Director
Industrial and Extractive Processes Div.
Office of Research and Development
U.S. Environmental Protection Agency
Washington, D.C.

SAB Liaison Member
Mr. John J. Convery, Director
Wastewater Research Division
Municipal Environmental Res. Laboratory
U.S. Environmental Protection Agency
Cincinnati, Ohio

Secretariat Responsibilities
Dr. Dennis E. Konasewich
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
EXPERT COMMITTEE ON
SOCIETAL ASPECTS OF GREAT LAKES WATER QUALITY

Professor Leonard B. Dworsky (Chairman)
Civil and Environmental Engineering
Cornell University
Ithaca, New York

Ms. Mimi Becker *(Effective February 1979)*
President
Great Lakes Tomorrow
Hiram, Ohio

Dr. G. R. Francis
Department of Man-Environmental Studies
University of Waterloo
Waterloo, Ontario

Dr. Paul Nickel *(Effective February 1979)*
Planning Director
Great Lakes Basin Commission
Ann Arbor, Michigan

Mr. H. D. Paavila *(Effective February 1979)*
Director
Environmental, Energy and Supply Services
Canadian Pulp & Paper Association
Montreal, Quebec

Mr. J. Castrilli *(Effective May 1979)*
Research Director
Canadian Environmental Law Association
Law Advisory Clinic
Toronto, Ontario

Professor C. P. Runge *(Effective May 1979)*
Director
Center for Public Policy & Administration
University of Wisconsin-Madison
Madison, Wisconsin

Professor J. L. Sax *(Effective May 1979)*
Faculty of Law
University of Michigan
Ann Arbor, Michigan

Dr. Edward G. Pleva
(Effective February 1979)
Department of Geography
Social Science Center
University of Western Ontario
London, Ontario

Mr. Leonard T. Crook *(Until February 1979)*
Water Resources Consultant
Ann Arbor, Michigan

Mr. John P. Hills *(Until February 1979)*
Mesenger, Lynch, Hills & Miller Associates
Beltsville, Maryland

<u>SAB Liaison Member</u>
Mr. J. Douglas Roseborough
Director, Wildlife Branch
Ontario Ministry of Natural Resources
Queen's Park, Parliament Bulilding
Whitney Block
Toronto, Ontario

<u>Secretariat Responsibilities</u>
Dr. A. E. P. Watson
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
TASK FORCE ON THE
HEALTH EFFECTS OF NON-NTA DETERGENT BUILDERS

Dr. James H. Day (Chairman)
Department of Medicine
Queen's University
Kingston, Ontario

Dr. G. C. Becking
Chief, Environmental Toxicology Division
Dept. of National Health and Welfare
Environmental Health Centre
Ottawa, Ontario

Dr. Larry Fishbein
Assistant to Director for
Environmental Surveillance
National Center for Toxicological Res.
Jefferson, Arkansas

Dr. David Gaylor *(Until October 1978)*
Statistician
National Center for Toxicological Res
Jefferson, Arkansas

Dr. R. A. Goyer
Deputy Director
National Institute of Environmental
Health Sciences
Research Triangle Park, N.C.

Dr. Arthur S. Kraus ***(Effective January 1979)***
Professor
Dept. of Community Health - Epidemiology
Queen's University
Kingston, Ontario

Professor R. O'Brien
Office of the Provost
University of Rochester
Rochester, New York

Dr. G. J. Stopps *(Until October 1978)*
Dept. of Preventive Medicine
University of Toronto
Toronto, Ontario

Liaison Members

Representing Soap and Detergent
Association of Canada
Mr. F. Alan Brownridge
Manager
Professional and Regulatory Service
Procter & Gamble Co. of Canada Limited
Hamilton, Ontario

Representing Soap and Detergent
Association, New York
Dr. Walter L. Schleyer
Government & Industry Relations Manager
PQ Corp.
Research and Development Center
Lafayette Hill, Penn.

Adjunct Members

Dr. R. Tardiff
Board on Toxicology and
Environmental Health
National Academy of Sciences
Washington, D.C.

Dr. S. I. Shibko
Chief, Contaminants and Natural
Toxicants Evaluation Branch
Division of Toxicology, HFF-195
Food and Drug Administration
Dept. of Health, Education and Welfare
Washington, D.C.

Secretariat Responsibilities

Dr. A. E. P. Watson
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
TASK FORCE ON THE ECOLOGICAL EFFECTS OF
NON PHOSPHATE DETERGENT BUILDERS

Professor Joseph Shapiro (Chairman)
University of Minnesota
Limnological Research Center
Minneapolis, Minnesota

Dr. Peter J. Chapman
Department of Biochemistry
University of Minnesota
St. Paul, Minnesota

Dr. Richard Dick
J. P. Ripley Professor of Engineering
Hollister Hall
Cornell University
Ithaca, New York

Dr. Peter Dillon
Water Resources Branch
Ontario Ministry of the Environment
Rexdale, Ontario

Dr. Charles R. O'Melia
Professor of Environmental Sciences
and Engineering
School of Public Health
University of North Carolina
Chapel Hill, North Carolina

SAB Liaison Member
Dr. Anne Spacie
Department of Fisheries and
Natural Resources
Purdue University
Forestry Building
West Lafayette, Indiana

Liaison Members
Representing Soap and Detergent
Association of Canada
Mr. F. Alan Brownridge
Manager, Professional & Regulatory Service
Procter & Gamble Co. of Canada Limited
Hamilton, Ontario

Representing Soap and Detergent
Association, New York
Dr. Flynt Kennedy
Manager, Chemical Research
Research and Development Department
Continental Oil Company
Ponca City, Oklahoma

Representing Fisheries and Environment
Dr. K. L. E. Kaiser
Environmental Quality Coordinating Unit
Canada Centre for Inland Waters
Burlington, Ontario

Representing U.S. EPA, Region V
Dr. William Fairless, Deputy Director
Central Regional Laboratory
Chicago, Illinois

Representing EPA - Office of Toxic Sub.
Ms. Justine Welch
Hazard Assessment Group
Office of Toxic Substances
U.S. Environmental Protection Agency
Washington, D.C.

Secretariat Responsibilities
Mr. David R. Rosenberger, Biologist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
PHOSPHORUS MANAGEMENT STRATEGIES TASK FORCE

Dr. Gerald A. Rohlich (Chairman)
Professor
Department of Civil Engineering
The University of Texas
Austin, Texas

Mr. Garth Bangay
Environmental Protection Service
Environment Canada, Ontario Region
Canada Centre for Inland Waters
Burlington, Ontario

Dr. A. M. Beeton
Director
Great Lakes and Marine Water Center
University of Michigan
Ann Arbor, Michigan

Dr. G. Anders Carlson
NY Dept. of Environmental Conservation
Bureau of Water Research
Albany, New York

Dr. Raymond C. Loehr
Professor and Director
Environmental Studies Program
Cornell University
Ithaca, New York

Dr. John Mancini, Professor
Environmental Engineering
Manhattan College
Bronx, New York

Dr. Donald J. O'Connor, Professor
Environmental Engineering
Manhattan College
Bronx, New York

SAB Liaison Member
Mr. John J. Convery
Director, Wastewater Res. Division
U.S. Environmental Protection Agency
Cincinnati, Ohio

Dr. Henry Peskin
Resources for the Future
Washington, D.C.

Mr. Steve Salbach
Ontario Ministry of the Environment
Water Resources Branch
Toronto, Ontario

Dr. Norman W. Schmidtke
Acting Director
Wastewater Technology Centre
Department of the Environment
Canada Centre for Inland Waters
Burlington, Ontario

Mr. Gordon Van Fleet
Ontario Ministry of the Environment
Pollution Control Branch
Toronto, Ontario

Mr. Gary Williams, Chief
Environmental Engineering Branch
U.S. Environmental Protection Agency
Chicago, Illinois

Dr. Stephen Yaksich
Corps of Engineers
Department of the Army
Buffalo, New York

Secretariat Responsibilities
Dr. Walter Rast
Limnologist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
TASK FORCE ON ENVIRONMENTAL MAPPING

Dr. Eugene J. Aubert (Chairman)
Director, Great Lakes Environmental
Research Laboratory
National Oceanic & Atmospheric
Administration
Ann Arbor, Michigan

Dr. Thomas Edsall
Great Lakes Fishery Laboratory
U.S. Fish and Wildlife Service
Ann Arbor, Michigan

Mr. Jack Christie *(Effective October, 1978)*
Fisheries Research Station
Ministry of Natural Resources
Picton, Ontario KOK 1TO

Dr. Murray G. Johnson
Director General, Ontario Region
Great Lakes Biolimnology Lab.
CCIW
Burlington, Ontario

Mr. Kenneth Loftus *(Until October, 1978)*
Director, Fisheries Branch
Ontario Ministry of Natural Resources
Whitney Block
Toronto, Ontario

Mr. Steven E. Salbach
Supervisor
Planning and Coordination
Water Resources Branch
Ontario Ministry of Environment
Toronto, Ontario

Dr. Peter G. Sly
Environment Canada
Glenora Fisheries Station
Picton, Ontario

Dr. D. F. Squires
Director
New York Sea Grant Institute, SUNY
Albany, New York

Dr. Edith Tebo
Director
Great Lakes National Program Office
U.S. Environmental Protection Agency
Chicago, Illinois

SAB Liaison Member

Mr. Carlos M. Fetterolf
Executive Secretary
Great Lakes Fishery Commission
Ann Arbor, Michigan

Secretariat Responsibilities

Mr. D. A. Bondy
Physical Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
STANDING COMMITTEE ON AQUATIC ECOSYSTEM OBJECTIVES

Dr. W. M. J. Strachan (Chairman)
Head, Toxic Substances Section
Process Research Division
National Water Research Institute
Canada Centre for Inland Waters
Burlington, Ontario

Mr. G. P. Brezner, Chief
Classification and Standards Division
Bureau of Standards and Compliance
N.Y. Dept. of Environmental Conservation
Albany, New York

Dr. William A. Brungs
Technical Assistance Director
Environmental Research Lab.-Duluth
Duluth, Minnesota

Dr. T. Brydges
Supervisor, Limnology & Toxicity Section
Water Resources Branch
Ontario Ministry of the Environment
Rexdale, Ontario

Dr. D. J. Hallet
Research Scientist
Wildlife Toxicology Division
Canadian Wildlife Service
National Wildlife Research Institute
Fisheries and Environment
Ottawa, Ontario

Dr. P. V. Hodson
Research Scientist
Great Lakes Biolimnology Laboratory
Canada Centre for Inland Waters
Burlington, Ontario

Dr. Eugene V. Perrin
Professor of Pathology
Wayne State University
School of Medicine
Detroit, Michigan

Dr. A. Robertson
Head, Chemistry & Biology Group
Great Lakes Environmental Research Lab.
National Oceanic & Atmospheric
Administration
Ann Arbor, Michigan

Mr. Richard A. Ryder
Head, Productivity Unit
Ontario Ministry of Natural Resources
Fish and Wildlife Research Branch
Thunder Bay, Ontario

SAB Liaison Member

Dr. Anne Spacie
Assistant Professor
Department of Forestry and Natural
Resources
Purdue University
West Lafayette, Indiana

Secretariat Responsibilities

Dr. D.E. Konasewich
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

JOINT SCIENCE ADVISORY BOARD/WATER QUALITY BOARD COMMITTEE
ON THE
ASSESSMENT OF HUMAN HEALTH EFFECTS OF GREAT LAKES WATER QUALITY

Mr. J. R. Hickman (Chairman)
Director, Bureau of Chemical Hazards
Health and Welfare Canada
Environmental Health Centre
Ottawa, Ontario

Dr. J. H. Aitken *(Until March 1979)*
Ontario Ministry of Labour
Toronto, Ontario

Dr. G. C. Becking *(Effective March 1979)*
Chief, Environmental Toxicology Div.
Dept. National Health and Welfare
Environmental Health Centre, Room 118
Ottawa, Ontario

Dr. G. Berg
Chief of Virology
Advanced Wastewater Treatment Res. Lab.
U.S. Environmental Protection Agency
National Environmental Research Center
Cincinnati, Ohio

Dr. Rita Bogoroch, Director
Health Effects Program
National Council of the Paper Industry for
Air & Stream Improvement (NCASI)
New York, New York

Dr. N. Chernoff
Health Effects Research Lab.
U.S. Environmental Protection Agency
Research Triangle Park, N.C.

Dr. James H. Day
Department of Medicine
Queen's University
Kingston, Ontario

Dr. R. W. Durham
Applied Research Division
Canada Centre for Inland Waters
Dept. of Fisheries and Environment
Burlington, Ontario

Dr. H. L. Falk
Associate Director for Health
Hazard Assessment,
National Institute of Environmental
Health Sciences
Research Triangle Park, N.C.

Dr. G. Wolfgang Fuhs, Director
Division of Laboratories and Research
N.Y. State Department of Health
Environmental Health Center
Tower Building, Empire State Plaza
Albany, New York

Dr. Rolf Hartung
School of Public Health 1
University of Michigan
Ann Arbor, Michigan

Dr. Harold E. B. Humphrey
Environmental Epidemiologist
State of Michigan
Department of Public Health
Lansing, Michigan

Dr. G. J. Stopps *(Until March 1979)*
Department of Preventive Medicine
University of Toronto
Toronto, Ontario

Mrs. Ann H. Vajdic *(Effective March 1979)*
Microbiologist
Water Technology Section
Pollution Control Planning Branch
Ontario Ministry of the Environment
Toronto, Ontario

ASSESSMENT OF HUMAN HEALTH EFFECTS OF GREAT LAKES WATER QUALITY

(Continued)

SAB Liaison Member
Dr. Mitchell R. Zavon
Medical Director
Hooker Chemicals
Niagara Falls, New York

Secretariat Responsibilities
Dr. A. E. P. Watson
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

Observers
Mr. Joseph Prince
Technical Support Section
U.S. Environmental Protection Agency
Region V, Water Division
Chicago, Illinois

Dr. Lyman Condie
Toxic Substances Coordinator
U.S. Environmental Protection Agency
Region V
Chicago, Illinois

GREAT LAKES SCIENCE ADVISORY BOARD
AD HOC ECOSYSTEM STUDY COMMITTEE

Dr. J. R. Vallentyne (Chairman)
Senior Scientist
Fisheries and Marine Service
Ontario Region
Canada Centre for Inland Waters
Burlington, Ontario L7R 4A6

Mrs. F. Edna Gardner
Islington, Ontario M9A 4L2

Dr. Joseph Kutkuhn
Director
U.S. Department of the Interior
Fish and Wildlife Service
Great Lakes Fishery Laboratory
Ann Arbor, Michigan 48105

Professor J. Llamas *(Until February 1979)*
Director, Water Resources Center
Faculty of Science and Engineering
Pavillon Pouliot
University of Laval
Centreau, Room 3717
Ste. Foy, Quebec G1K 7P4

Dr. James H. Day *(Effective February 1979)*
Department of Medicine
Queen's University
Kingston, Ontario

Dr. Anne Spacie
Department of Fisheries and
Natural Resources
Purdue University
West Lafayette, Indiana 47907

<u>Secretariat Responsibilities</u>
Mr. David R. Rosenberger, Biologist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario N9A 6T3

GREAT LAKES SCIENCE ADVISORY BOARD
REVIEW COMMITTEE FOR THE
DISSOLVED OXYGEN OBJECTIVE FOR THE GREAT LAKES

Dr. John J. Magnuson (Chairman)
Laboratory of Limnology
University of Wisconsin
Madison, Wisconsin

Dr. Paul O. Fromm
Department of Physiology
Michigan State University
Giltner Hall
East Lansing, Michigan

Dr. J. R. Brett
Fisheries Research Board
Pacific Biological Station
Nanaimo, B. C.

Dr. F. E. J. Fry
10 Riverlea Road
Weston, Ontario

Secretariat Responsibilities
Dr. A. E. P. Watson
Research Scientist
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, 8th Floor
Windsor, Ontario

GREAT LAKES SCIENCE ADVISORY BOARD
1979 ANNUAL REPORT DRAFTING COMMITTEE

Dr. Donald I. Mount
Director
Environmental Research Laboratory-Duluth
Duluth, Minnesota

Dr. G. K. Rodgers
Director
National Water Research Institute
Canada Centre for Inland Waters
Burlington, Ontario

Dr. Dennis E. Konasewich
Research Scientist
International Joint Commission
Great Lakes Regional Office
Windsor, Ontario

Mr. David R. Rosenberger
Biologist
International Joint Commission
Great Lakes Regional Office
Windsor, Ontario